AUGUST 1955

THE WELDING JOURNAL

IN THIS ISSUE

Maintenance Welding and Cutting on Radioactive Equipment 731
Fabrication of Bridge Plate Girders 741
Inert Arc Welding of Pressure Piping 747
Iron-Powder Coated Electrodes for Production 752
New Concepts on Welding Qualification Requirements 759
Properties of Austenitic Stainless Steels 361-s
Effect of Pretreatment of Martensite on Graphitization 374-s
Weldability of Titanium Alloy Sheet—Part 1 . . . . . 379-s
Notation System for Pressure-Vessel Shell Theory 393-s
Modified Navy Tear Test 396-s

Table of Contents 727
Editorial 729
AWS Spring Meeting and Show. 771
Index to Advertisers 830

OFFICIAL PUBLICATION OF THE AMERICAN WELDING SOCIETY

Effects "DOUBLE" Protection:

"SPEEDY"

No. 5000 ATTACHMENT

A FIBRE-METAL EXCLUSIVE!

NEW No. 5000 "SPEEDY" ATTACHMENT...

1) Converts Welding Helmet to Safety Cap Use
2) Readily Adapts to Caps in Field
3) Fits All Popular Peak-type Caps
4) Attaches or Detaches Cap Instantly

THIS INGENIOUSLY DESIGNED, *yet simple to use,* "SPEEDY" Attachment adapts the welding helmet for use with a Safety Cap to provide *both* eye and head protection for the Welder when he works under conditions where there is danger of head injury from falling or flying objects.

"SPEEDY" is economical both as to cost and in speed of attachment . . . or detachment! It represents very practically FIBRE-METAL's long experience and ability to provide the best possible *products for protection* that also help make the most profitable use of a man's time.

The No. 5000 "SPEEDY" Attachment consists of two rugged steel Clips with insulated prongs to grip the edge of the Safety Cap; a sturdy, replaceable Neoprene Strap connecting the Clips and providing tension over the top of the Cap. Friction joints hinge helmet on cap. Write for Bulletin No. 43.

No. 5000 "SPEEDY" FEATURES:

- LONG LIFE. ECONOMICAL, PRACTICAL
- SPEEDY ON OR OFF
- FITS ALL POPULAR PEAK-TYPE CAPS
- NO HOLES IN CAP
- NO HARDWARE ON CAP
- CONTINUOUS HEAD PROTECTION
- ADAPTS PRESENT HELMETS TO COMBINATIONS

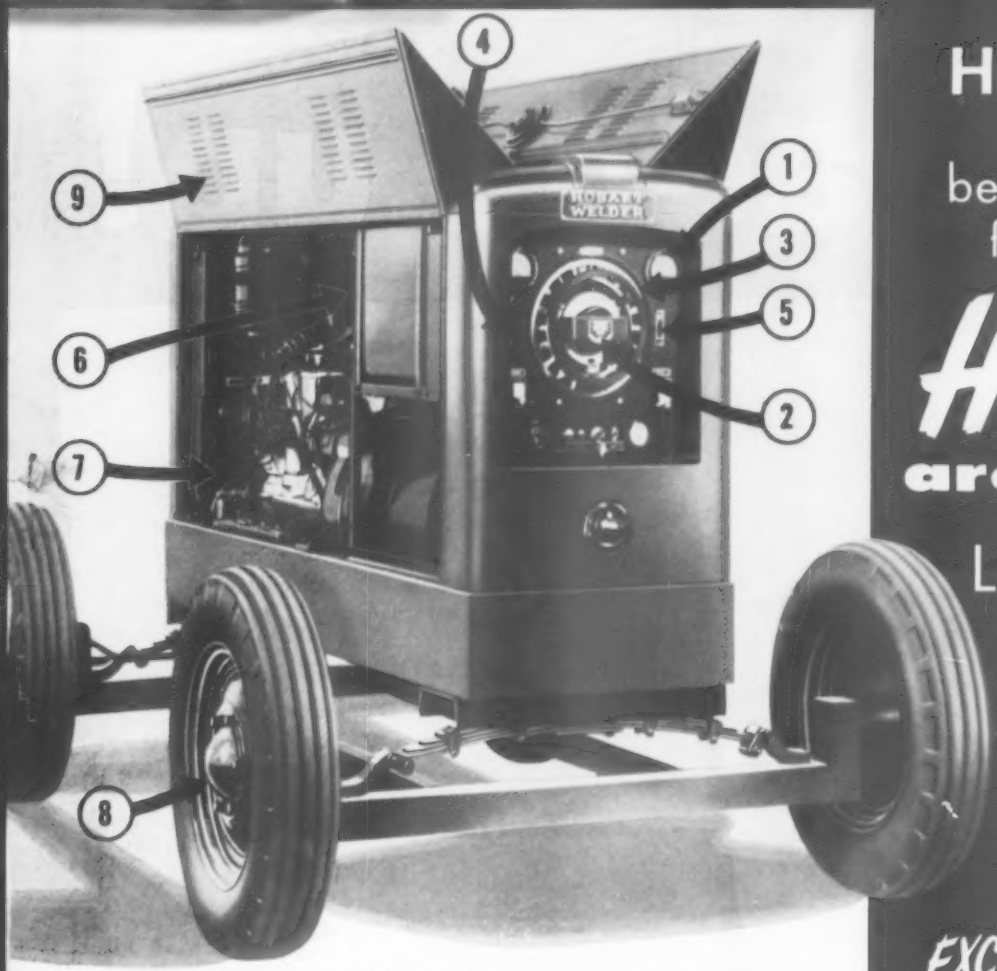
When buying any protective equipment...always ask for a FIBRE-METAL *product!*

FIBRE-METAL
PROFITABLE PROTECTIVE PRODUCTS SINCE 1905

THE FIBRE-METAL PRODUCTS CO.

Sold Everywhere thru leading Distributors and Dealers

Here's WHY you get better welding faster with HOBART arc welders



Look inside

. . . check the engine
. . . check the generator
. . . check the performance

for famous HOBART QUALITY
. . . plus the

EXCLUSIVE FEATURES

that give you low welding costs

1 Convenient Control Panel
2 Remote Control for improved quality of welds
3 Dual Control gives 1000 combinations of welding heat
4 Convenient Polarity Switch
5 1 KW DC receptacle for auxiliary power
6 Automatic idling control
7 Push button self starting industrial engine
8 Your choice of sturdy portable mountings
9 Protective steel canopy with hinged side panels

(METERS OPTIONAL)

Leading contractors, pipeline builders and metal working shops everywhere find this new Hobart Gasoline Engine Driven Welder costs less, does more.

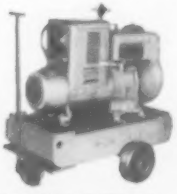
YOU'LL FIND Hobart Arc Welders are the most complete welder units on the market today. The best proof of Hobart's superior advantages and values is comparison with other welders. Try a Hobart—see why you get more actual benefits in dollar savings and increased profits because of its higher performance, faster welding and lower cost operation.

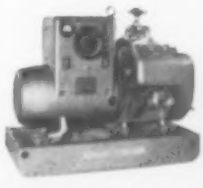
"One of the world's largest builders of arc welders"

Hobart Brothers Co., Box WJ-85, Troy, Ohio, Phone 21223

Electric Drive

Transformers


Air Cooled "Husky Boy"


Air Cooled AC Power—AC Welder

Look to HOBART for Better ELECTRODE VALUES

Hobart's complete line of electrodes offers you a practical solution to every welding problem. You'll find a size and type best suited to meet your particular requirements on every job. Write for complete electrode catalog.

Hobart Bros. Co., Troy, Ohio, Phone 21223

☐ Tell me about _____ amp. capacity
☐ Gas Drive ☐ Electric Drive ☐ AC Transformer
☐ Husky Boy ☐ AC Welder—AC Power. Our work is

NAME _____ POSITION _____
FIRM _____
ADDRESS _____
☐ Would like to try sample of Hobart Electrodes for (type of work) _____

It all adds up!

Arc and Thermit welders for years have looked to Metal & Thermit for the electrodes, machines, and accessories they need, and for the research, engineering data, technical assistance, and ordering convenience that Metal & Thermit can offer. To the thousands of welders specifying M&T equipment, it all adds up to profitable welding. You, too, can enjoy the same unsurpassed purchasing economy and technical assistance by which so many others profit. Write now or call your M&T man for information on your requirements. There's one near you.

M&T welding products include:

MUREX ELECTRODES for

mild steel — aluminum bronze
low alloy steel — cast iron
stainless steel — aluminum
hard surfacing

M&T WELDING MACHINES

A.C. transformers — D.C. motor generators
D.C. rectifiers — D.C. engine driven
Inert arc

M&T WELDING ACCESSORIES

holders — helmets
cleaning tools — lugs
cable — gloves
ground clamps

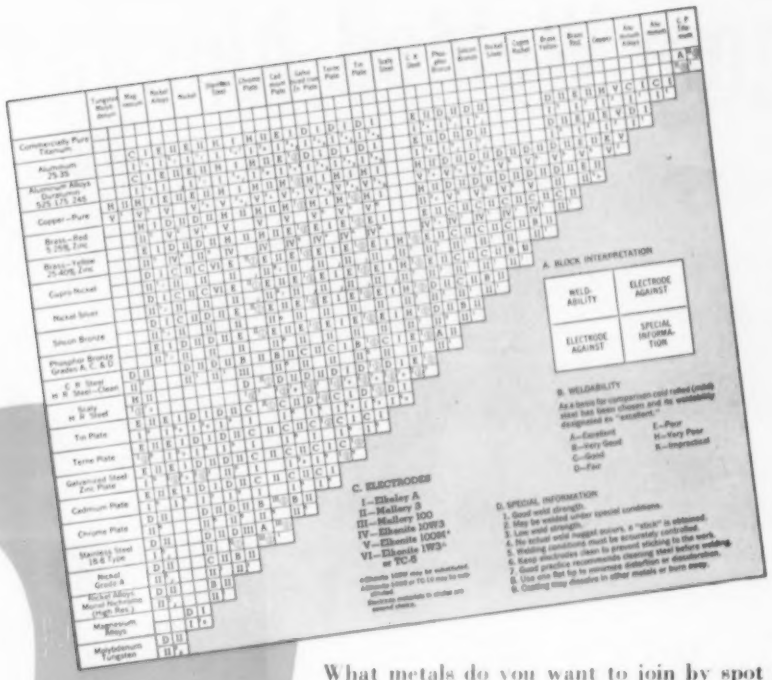
THERMIT WELDING MATERIALS and ACCESSORIES

for the fast, low-cost fabrication and repair of heavy equipment.

METAL & THERMIT CORPORATION

Welding Division

100 EAST 42nd STREET, NEW YORK 17, N. Y.



For your spot welding jobs

Are you using the right electrode alloy

What metals do you want to join by spot welding? For over 200 different metal-to-metal combinations, the chart pictured here can give you a lot of valuable welding data. Based on many years of laboratory study and field experience, it tells you at a glance—

- The recommended Mallory alloys to use as electrodes against each metal.
- The weldability you can expect.
- Special information on welding techniques to be followed.

This "electrode recommendation chart" is just one of the many useful features you will find in the Mallory Welding Catalog. Described in this publication are the unequalled variety of welding alloys which Mallory has developed to meet every welding requirement . . . to provide the best combinations of conductivity, hardness, strength and wear resistance in hundreds of different designs. Mallory electrodes, holders, seam welding wheels, forgings, castings and dies are listed, for your convenience in planning effective and economical welding set-ups.

Get a copy of this catalog from your Local Mallory Welding Distributor. And if you have a welding problem, ask your distributor or write directly to Mallory for recommendations on electrodes, alloys, holders and techniques that can save your production time and money.

Expect More . . . Get More from

P. R. MALLORY & CO. Inc.

MALLORY

P. R. MALLORY & CO., Inc., INDIANAPOLIS 6, INDIANA

In Canada, made and sold by Johnson Matthey and Mallory, Ltd., 110 Industry Street, Toronto 15, Ontario

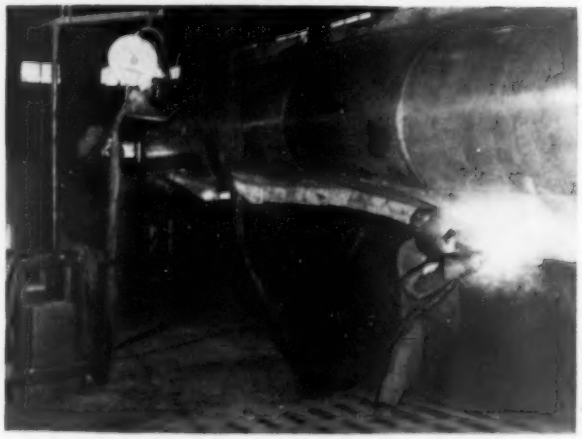
Serving Industry with These Products:

Electromechanical—Resistors • Switches • Television Tuners • Vibrators
Electrochemical—Capacitors • Rectifiers • Mercury Batteries
Metallurgical—Contacts • Special Metals and Ceramics • Welding Materials

For information on titanium developments, contact Mallory-Sharon Titanium Corp., Niles, Ohio

Sigma Welded Aluminum Tanks

—WEIGH LESS
—CARRY MORE
—LAST LONGER



The problem of how to get bigger pay-loads in truck trailers and semi-trailers was solved by one manufacturer who converted to weight-saving aluminum and sigma welding . . . These giant semi-trailer tanks hold 7,950 gal.—700 gal. more than similar tanks made of steel.

The high quality of sigma welded aluminum has increased tank resistance to corrosion. Sigma welding has also eliminated expensive weld cleaning—welds need only a light grinding and they are finished. Each semi-trailer requires about 1,100 linear ft. of sound sigma welding. The new high-strength, ductile alloys used range in thickness from 3/32 to ½ inch.

Like many other products throughout industry, these trailers are being fabricated with new quality and efficiency using sigma welding.

Here are some features of sigma welding—

- Uses any d.c. or constant potential power supply. With c.p. voltage is held constant—welding operations are fast and more efficient.
- Makes smooth welds in joints of all types—on all commercially welded metals . . . joins metals up to ¼ in. thick in one pass.
- Sigma welding speeds exceed 100 in. per min. in many operations. Start saving now, call your local LINDE representative for more information—and ask for Form 7942 "Modern Methods of Joining Metals."

Linde Air Products Company
A Division of Union Carbide and Carbon Corporation
30 East 42nd Street UCC New York 17, N. Y.
Offices in Other Principal Cities
In Canada: LINDE AIR PRODUCTS COMPANY
Division of Union Carbide Canada Limited, Toronto
(formerly Dominion Oxygen Company)
The term "Linde" is a registered trade-mark of Union Carbide and Carbon Corporation.

Linde
Trade-Mark

THE WELDING JOURNAL

VOLUME 34 • NUMBER 8 • AUGUST 1955

TECHNICAL PAPERS, ITEMS AND REPORTS

Editorial—*The Printed Word, by A. G. Oehler* 729

Maintenance Welding and Cutting Operations on Radioactive Process Equipment, by E. B. LaVelle and J. M. Fox, Jr. 731

Fabrication of Bridge Plate Girders by Submerged Arc Welding, by Joseph H. Hoffman ... 741

Joint Detail for Inert Arc Welding of Pressure Piping, by R. T. Pursell 747

Evaluating the Iron-Powder Coated Electrodes for Production Use, by Donald B. Howard .. 752

Some New Concepts on Welding Qualification Requirements, by S. A. Greenberg 759

Editorial Previews—Sciaky Opens Western Research Division 761

Current Welding Literature 770

PRACTICAL WELDER AND DESIGNER

Popular Wrought Iron Furniture Is Easily Made by Braze Welding, by A. J. Beldon 763

Ten-Second Tab Tacker, by J. R. Fullerton 766

Structural Steel Welding, by A. L. Fenlason 768

SOCIETY AND RELATED EVENTS

Society News 771

AWS Spring Meeting and Show 771

Technical Papers Sessions—1955 National Fall Meeting 789

Section News and Events 794

New Members 802

Abstracts of Current Patents 805

News of the Industry 808

Personnel 816

Employment Service Bulletin 819

New Products 820

New Literature 826

Index to Advertisers 830

WELDING RESEARCH SUPPLEMENT

Tension-Impact Properties of Austenitic Stainless Steels at Ambient and Low Temperatures, by A. Choquet, V. N. Krivobok and G. Welter 361-s

Effect of Pretreatment of Martensite on Subsequent Graphitization at 1200° F, by G. V. Smith, E. J. Dulis and B. W. Royle 374-s

Electrolytic Welding and Brazing, by P. Zuffa 378-s

Effects of Interstitial Elements on the Weldability of Titanium Alloy Sheet—Part 1, by H. M. Meyer 379-s

Uniform Notation System for Pressure-Vessel Shell Theory 393-s

Modified Navy Tear Test for Measuring the Work of Fracture Propagation in Ductile Metals, by Hugh E. Romine 396-s

Published for the advancement of the science and art of welding by the American Welding Society

Published monthly by the American Welding Society. Publication office, 20th and Northampton Streets, Easton, Pa. Editorial and general offices, 33 West 39th St., New York 18, N. Y. Subscriptions $7.00 per year in the United States and possessions; foreign countries $8.50. Single copies, nonmembers $1.00; members 75 cents. Entered as second-class matter January 5, 1932, at the Post Office at Easton, Pa., under the act of March 3, 1879.

Copyright 1955, by the American Welding Society. The Society is not responsible for any statement made or opinion expressed in its publications. Permission is given to reprint any article after its date of publication provided credit is given.

How NI-ROD "55" welded the lift back into this lift truck

saves $195 on the price of a new iron casting

This fork lift truck, used in a Connecticut warehouse, was completely out of commission.

Two important cast iron lugs that support the steel tilt shaft had broken. (The tip of the pencil points to the inside of one lug; the light area to the left of the pencil tip is the upper side of the lug.)

A new casting with those support lugs on it would cost $260 . . . and plenty in labor to install! Should they buy it? Or scrap the truck?

The warehouse manager had another idea: *welding*. He called in Tommy's Welding Service of Glenbrook.

Tommy Behan said if the repair could be made, he could do it . . . with NI-ROD "55" electrodes.

First, he ground a full vee in each cast iron lug and filled them in with Ni-Rod "55". Next, he welded a ¼-inch steel band to each. Then, he welded a third band to the casting between the lugs for added support. Finally, he welded steel pipe couplings to the center support lug as a bearing for the shaft.

The whole job was done with 5/32-inch diameter NI-ROD "55" electrodes. And it cost the warehouse only $65!

Welding was possible because easy-handling NI-ROD "55" electrodes produce sound ductile deposits in cast iron, and in welding cast iron to other metals like steel.

Get this helpful new booklet

If you want more information on successful cast iron welding, send for the latest Inco booklet on NI-ROD "55"® and NI-ROD®. It gives you the actual facts on the success others have had in welding *a wide variety of castings with these companion nickel and nickel-iron electrodes*. Also tells you which of the two is generally preferred in different jobs . . . how to use them . . . what advantages you'll discover. Write Inco for this valuable booklet today.

The INTERNATIONAL NICKEL COMPANY, Inc.
67 Wall Street New York 5, N. Y.

INCO Welding Products
TRADE MARK
Electrodes • Wires • Fluxes

THE
WELDING
JOURNAL

Editor
B. E. Rossi

Assistant Editor, Production
Catherine O'Leary

Officers of the Society

J. H. Humberstone
President
J. J. Chyle
1st Vice-President
C. P. Sander
2nd Vice-President
R. S. Donald
Treasurer
J. G. Magrath
Secretary
F. J. Mooney
Asst. Secretary
S. A. Greenberg
Technical Secretary

District Directors

1. *New England*
H. Hugo Stahl
2. *Middle Eastern*
D. B. Howard
3. *North Central*
Clarence E. Jackson
4. *Southeast*
A. E. Pearson
5. *East Central*
J. H. Blankenbuehler
6. *Central*
J. R. Stitt
7. *West Central*
A. F. Chouinard
8. *Midwest*
H. Jackson
9. *Southwest*
J. B. Davis
10. *Western*
R. H. Smith
11. *Northwest*
Clarence M. Styer

THE PRINTED WORD

Some things we learn by experience. That is the hard way. It leaves a mighty permanent record in a man's mind, but it is not enough. One man cannot experience all things and he must learn from others.

There are basically but two ways in which knowledge may be passed from one person to another. One is by sound and the other by sight.

The teacher in the classroom or the speaker on the platform passes information to his class or his audience. But it comes fast and most of it goes the same way. Listeners may have the privilege of asking questions, but at best this is an incomplete procedure. The speaker may augment his talk with pictures or diagrams, but they must appear and disappear. It may help a little to put the story on film and go over it many times, but that is a pretty deadly ordeal for the student. Private conversations with drawings on the table cloth are effective, but they too are fleeting.

Not until the word and picture are printed can they most effectively fulfill the needs of the man who wants to know. Then a point not understood can be gone over until it becomes the property of the reader. The filed copy also serves as an always available reference.

As one who has long been affiliated with THE WELDING JOURNAL and those who contribute to it, I feel justified in saying there is no other better single source of information on welding and its many ramifications. He who really uses the JOURNAL will acquire a vast knowledge of the subject and that knowledge will be his. Reference files and libraries made up of printed words are essentials to every professional man, but what is in your head is yours. It constitutes no burden to carry it about, you pay no taxes on it and it is instantly available when you need it.

A. G. Oehler
MEMBER
WELDING JOURNAL COMMITTEE

Tempilstik°

FOR ALL

HEAT-DEPENDENT

OPERATIONS

looks like a crayon...

marks like a crayon...

tells temperatures like a precision instrument!

Sixty-three different compositions enable you to determine and control working temperatures from 113° to 2000° F.

TEMPILSTIK° marks on workpiece "say when" by melting at stated temperatures—plus or minus 1%.

Also Available in Liquid and Pellet Form ...Write Accessories Div. For Sample Tempil° Pellets ... State Temperatures of Interest—Please!

Tempil°
CORPORATION
132 WEST 22ND STREET
NEW YORK 11, N. Y.

How Tempilstiks° are used

● TEMPILSTIKS° are temperature-sensitive crayons of calibrated melting points. There are some sixty-five different TEMPILSTIKS° in the range from 113°F to 2000°F, each indicating a specified temperature, within a tolerance of plus or minus 1% of its rating.

The appropriate TEMPILSTIK° is selected and, for most applications, the work-piece is marked with it before heat is applied. On subsequent heating the crayon-like mark of the TEMPILSTIK° melts as soon as its temperature rating is reached.

The mark made by a TEMPILSTIK° may gradually change in color as heating progresses. The change in color, or in color intensity, is never to be interpreted as a temperature indication. The TEMPILSTIK° mark melts when its temperature rating is reached and only this change from the dry to the liquid condition is the significant temperature signal.

In some applications this simple method may not suffice because evaporation of the TEMPILSTIK° mark on prolonged heating, or its gradual absorption by the surface at high temperatures, may leave too little residual substance for unambiguous observation. In such cases stroking or touching the work-piece with the TEMPILSTIK° at regular intervals during the heating process is recommended. The TEMPILSTIK° will leave a dry mark at temperatures below its rating and a liquid streak when its temperature rating has been reached or exceeded. If the workpiece is not accessible for applying a TEMPILSTIK° during the heating process, then TEMPILAQ°, or possibly TEMPIL° PELLETS, should be used instead.

TEMPILSTIKS° will usually glide over unheated polished surfaces (like glass, polished stainless steel, etc.) without leaving an appreciable mark. Therefore, in applications that involve smooth or polished surfaces TEMPILSTIKS° should be used by touching or stroking the workpiece periodically during the heating process, as previously described, because a liquid streak will be made on contact as soon as the specified temperature is reached. Where it is necessary to mark a smooth work piece surface prior to heating, TEMPILAQ° should be used.

A hot radiating surface will appear relatively dark under intense illumination from an external source, and this fact can be utilized to improve recognition of the temperature signal against a red-hot background. The use of TEMPIL° PELLETS or TEMPILAQ° instead of TEMPILSTIKS° will further improve visibility under these conditions.

On rapidly moving objects, like magnesium or aluminum sheet during spinning operations, it is impossible to see whether the applied TEMPILSTIK° leaves a dry or melted mark. However, with a little experience operators quickly learn to sense the smooth gliding of a TEMPILSTIK° over a surface which is hot enough to melt it on contact, as contrasted to the frictional drag on a cooler surface. If the top of the TEMPILSTIK° is brought in contact with the moving metal surface for a brief moment at a time, and with light pressure only, the heat contribution of friction is trivial enough to be ignored.

The above described "sensing technique" may also be employed on hot radiating surfaces where the bright background makes it difficult to distinguish whether or not the TEMPILSTIK° mark had melted.

An appropriate series of TEMPILSTIK° marks, applied to the workpiece or surface under investigation before heating begins, will provide a record of the maximum temperature attained during a process or operation. Subsequent examination will show that all TEMPILSTIK° marks up to a certain temperature rating had melted, while those of a higher rating had not. The maximum attained temperature must consequently lie somewhere in the interval between the highest melted and the lowest unmelted TEMPILSTIK° rating.

The temperature distribution and isothermal boundaries of surfaces such as furnace walls, melting ladles, cement kilns, etc., can be established by using an appropriately chosen series of TEMPILSTIKS° to draw a pattern of lines (parallel, concentric, radial, etc.) on the area under investigation. The heat conduction along a surface can be effectively studied by the progressive melting of suitably chosen TEMPILSTIK° lines. Caution must be exercised not to permit the mark made with one TEMPILSTIK° rating to cross or overlap the mark of a dissimilar TEMPILSTIK°, as such a mixing of different TEMPILSTIK° marks would destroy their accuracy.

TEMPIL° products will give good results in induction heating and in ionized air, as well as in the presence of static electricity about electrical equipment, where electrical means of measuring temperatures often function erratically.

Fig. 1 Welder using shielded metal arc welding to replace failed section of stainless steel piping in a process installation

MAINTENANCE WELDING AND CUTTING OPERATIONS ON RADIOACTIVE PROCESS EQUIPMENT

By E. B. LAVELLE and J. M. FOX, JR.

Detailed preparations using protective clothing and devices, timed movements and rehearsed steps protect personnel and assure satisfactory maintenance welding operations

SYNOPSIS. The normal problems of plant maintenance are considerably complicated whenever the maintenance is required in an atomic energy facility, and the relative cost is very high when compared to contact maintenance operations. However, in the 11 years since Alamagordo, a considerable technique in plant maintenance of radioactive facilities has been developed. Radiation permissible limits are known, work intervals are established and controls are imposed. Safety of personnel is the paramount consideration and the Safety Record at the Hanford Atomic Products Operation indicates the care exercised. Detailed preparations using protective clothing and devices, timed movements and rehearsed operations protect personnel and insure success of the specific maintenance welding operation. Some modification of existing welding equipment and techniques is indicated in order to overcome the problems encountered. There is need for recognition of these problems by the welding equipment industry so that as atomic energy develops into wide industrial use, equipment will be available to maintain it. These factors are discussed within security limitations. Types and kinds of radiation and methods of decontamination are briefly discussed. The paper points up the unique conditions encountered in welding maintenance of atomic installations. A need for remotely controlled apparatus is seen as well as for more comfortable and practical welding clothing.

Introduction

A new environmental factor, radioactivity, has entered the industrial plant. In the last ten years a body of knowledge has been developed by working with this factor. Changes in the Atomic Energy Act in 1954 will allow industrial concerns to engage in commercial activities in the nuclear field. Newcomers to this type

E. B. LaVelle is Senior Welding Engineer for the Engineering Department, and **J. M. Fox, Jr.**, is Plant Metallurgical Engineer for the Manufacturing Department, General Electric Co., Hanford Atomic Products Operation, Richland, Wash.

Presented at AWS National Spring Meeting held in Kansas City, Mo., June 7-10, 1955.

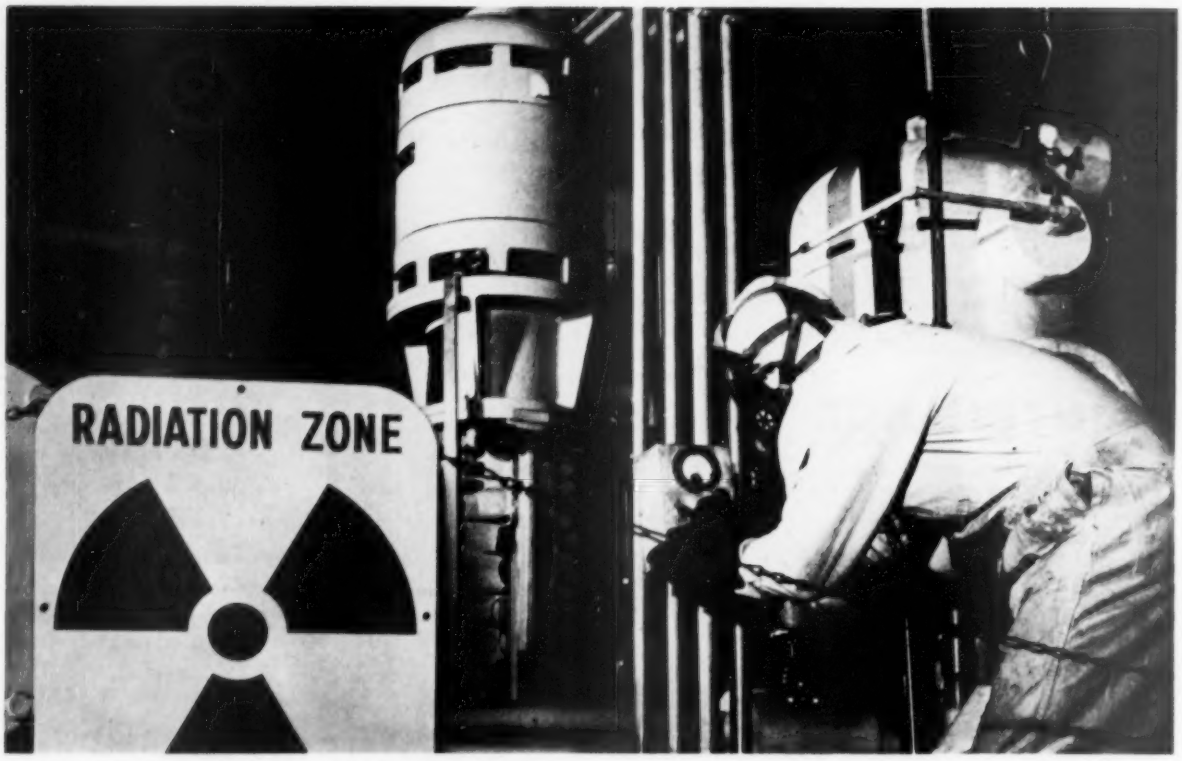


Fig. 2 Monitoring man surveying contaminated area

of business will find standard operations, processes, costs and plant maintenance colored by the highly specialized requirements inherent in this field. It may prove of interest to describe how one plant has handled maintenance operations successfully over a decade under such conditions.

A great deal has been said about the danger of working with radioactive materials. With proper consideration for the hazards involved, working conditions can be made as safe as those in any industry. Adequate training of people and competent supervision, combined with proper planning, will meet any situation that can be encountered in such work.

Plutonium, the material produced at Hanford, is not easily manufactured. It is a new element created by nuclear fission. The process of its manufacture and the materials with which it is associated give off very large amounts of radiation. We are concerned basically with high-energy radiation when working with atomic energy. High-energy radiation emerges from the nucleus of the atom. Hence, it is more properly termed nuclear energy, rather than atomic energy. There are several different classes of radiation, but the effect of all is similar on living cells and living tissue; the tissue is ionized by the radiation. The type of injury is the same, but the degree of damage may be different. The kinds of radiation with which we are concerned are (1) alpha particles, (2) beta particles, (3) gamma rays and (4) neutrons. Alpha particles are large, highly damaging particles. They cannot penetrate the unbroken skin, but if an element liberating them is deposited within the human body they may cause extreme damage. Beta particles are moderately damaging, moderately penetrating particles. They may penetrate up to a third of an inch of tissue. Gamma rays are electro-magnetic radiations which are highly penetrating but less damaging, quantity for quantity, than alpha and beta particles. High-energy neutrons can penetrate several feet of organic tissue.

Limits of exposure to radiation and standards of protection were developed from basic work that had been done with radium and X-rays. It was known from injuries that had been suffered by laboratory workers working with radium and exposed to X-rays that protective measures must be given adequate consideration. Working in the laboratory and working on radioactive equipment that must be maintained in a plant are quite different. To anticipate all conceivable conditions of maintenance of radioactive equipment requires detailed and meticulous attention. However, proper planning and adequate preparation for the job involved always results in a satisfactory maintenance operation.

Design Standardization

Design trend is toward greater standardization so that maintenance operations will be standardized along with the obvious benefits arising from the requirements for fewer items of spare equipment.

Standardization and simplification in the use of welding tools and materials and protective clothing for certain specific jobs simplify the maintenance operation to a considerable degree. *Simplification* of design will also make the task of the maintenance welder much easier.

It is necessary to provide process equipment having as long an anticipated service life as possible, and the time spent in design, though rather detailed by normal standards, seems to be justified if additional longevity and simplicity can be achieved. Mechanical simplicity is the requirement sought. This not only presupposes less operational difficulties, but offers greater possibility of maintenance in case of failure.

Equipment Contamination

The contamination of process equipment ordinarily results from the deposit or attachment of finely divided radioactive substances on the surface of the metallic material. The degree of radiation emitted by these particles may range from insignificant to that which effectively prevents handling except by remote methods where the operator is shielded from the operation by lead, concrete, water or comparatively great distances. Because of the nature of the equipment, removal of these contaminating substances may be very difficult. It may be impossible in a substantial number of instances. A further complication is that the metallic material of which the equipment is fabricated may itself become radioactive after long exposure to intense neutron radiation. The radioactive life of the deposited material may range from several seconds to thousands of years. It is possible in certain instances to set the equipment aside and permit the radioactivity to decay to a level which permits practical working time limits, or else to render the equipment suitable for standard decontamination methods for removal of the contaminating material. Ordinarily, the course of action is decided when the level of radioactivity is determined for the specific item of equipment.

In certain instances when the unit is extremely radioactive and cannot be decontaminated to the extent that welding or cutting operations are possible, it must be replaced. Spare equipment is provided for this purpose. The operation of replacing certain process equipment is very costly and time-consuming, and it would be very helpful if contact maintenance could be performed on all such units. With some, however, the level of radioactivity is so high that attempts to decontaminate to a workable level would be futile. There is no way of avoiding disposal of such equipment. Considering that certain replacement operations are done by remote means with the operator observing the equipment through a periscope or mirror, the difficulty of overcoming unforeseen occurrences can be understood.

Radiation Survey

No maintenance operation is considered without an adequate survey for radiation in the work area. It is anticipated that, as further information is developed, even more effective protective measures can be used and thus extend the working period for personnel exposed to radiation of the various kinds.

A radiation survey of a work area involves a thorough search for radioactive material. This is done with various electronic instruments provided for that purpose. The location and intensity of radiation is made a matter of record. This permits maintenance personnel to determine whether it is practical to attempt decontamination of the job area and repair the specific item or whether replacement is indicated. A radiation survey may also indicate that certain equipment is abnormally subject to contamination and that future design changes are indicated for similar equipment. The physical operation of surveying a work area for harmful radiation is simple, but requires painstaking effort by a highly skilled radiological technician.

The 1954 revisions to the Atomic Energy Act envision greater private and industrial participation in the use of nuclear facilities. Up to the present, such activities have been restricted to specialized groups working under Government auspices. It can be conjectured that, in the future, a number of industries will be doing nuclear work on an extensive scale in many localities throughout the country. As this trend develops, a description of the effect of radioactivity on standard industrial operations is timely.

Fig. 3 Welder and radiation monitoring man ready to approach a radioactive repair job

It will be necessary for the industrial concerns moving into the radiological field to familiarize themselves with the mechanics of dealing with the problems contingent upon such operations. A new work philosophy is involved. Up to the present time, prime consideration has been given to expeditious and effective accomplishment of the work under standard personnel safeguards. The overriding concern in atomic installations is that of adequate protection of personnel engaged in standard operations which are markedly affected by this new environmental factor. There is no wish to dodge this responsibility, and we wish to mention the safety record established at Hanford in 11 years of operation. This record is the standard method of accident tabulation that is used throughout industry. It is given here to illustrate that the element of radioactivity in our maintenance work has not adversely affected the record.

The Hanford Atomic Products Operation has won the sixth consecutive Award of Honor. This is offered by the National Safety Council for outstanding safety performance. During the period from February through September 1954, we worked over 9,400,000 man-hours without a disabling injury. During 1954, our major injury frequency rate was 0.31, while that for all industry during 1953 averaged 7.44. Our major injury severity rate during 1954 was 19.0, while that for all industry during 1953 averaged 830. We would shudder to work in an explosive factory, or a steel mill or in a mine. Actually, we are safer in this operation than we are at home or on the highway.

Actual practice exposes the worker to less than the radiation level established to control exposure of personnel. There is no case of serious overexposure of a worker at the Hanford Atomic Products Operation in the history of the plant.

An Advisory Board on Safety and Industrial Health, a group of 12 distinguished authorities, appointed by the Atomic Energy Commission to survey practices in the fields of various phases of working with radioactive materials, reported in 1948: "History affords no parallel to the thorough study of, and protection against, radiation hazards to workers, from inception of the project to the present." In establishing its safeguards, the Commission has, whenever possible, adopted and used the standards established by the National Committee on Radiation Protection. One of the important standards established by this Committee estimated the amount of whole-body radiation which a man could tolerate day after day without damage to himself. Extensive research programs have been established to explore more fully the danger of radiation to living matter, to develop more efficient instruments for detecting radiation, to devise new techniques for handling radioactive materials and to familiarize workers with the best methods of safer procedures for working with radioisotopes.

Maintenance Practices

So much for the general background of the problem.

Fig. 4 Health instrument man monitoring a welder who has just completed a repair job that was radioactive

All facets of normal industrial procedures are affected by radioactivity, but none, perhaps, as greatly as maintenance practices. Proper maintenance has always been a subject of much concern and study. In the atomic energy field, the impact of radioactivity upon maintenance has been enormous and a whole new philosophy has been developed. As one example—design often is governed entirely by maintenance experience on a piece of equipment. This approach is used in the more enlightened industrial fronts, but when dealing with radiation, it frequently becomes mandatory to establish maintenance parameters as design criteria.

Within the maintenance framework, cutting and welding are essential tools, and even in atomic installations have not changed as much as we would wish in the essentials of equipment or operation. The way in which they are used and the conditions under which they are used single out cutting and welding for attention. This paper will briefly describe how maintenance cutting and welding operations are performed under radiation control conditions. At first blush, it would appear that the operations are standard, the equipment is standard, and the results are standard. These are the things with which we are all familiar and they are not hard to visualize; it is the new factor of radioactive contamination or the presence of radiation that creates a difference—the reason why, for example, even though a weld bead may need only 1 in. more to be complete, the weld is stopped and a new welder completes the job; or a 10-min cutting job may

involve a meteorological report, an hour's setting-up time, a portable exhaust fan, a hood and a filter.

Under normal conditions of plant maintenance in industries other than those concerned with the processing of radioactive materials, maintenance procedures have become fairly standardized through continued repetitious work. Welding and cutting operations have, for many years, been an indispensable part of this kind of work. The use of these tools is well known to operators, and their place in the maintenance operation is understood by those planning such activities. Considerable information has been available to industry for a long time as to the cost of such operations and the details attending their use. These could be fitted into a schedule with fair ease. However, with the necessity for maintenance work to be performed on radioactive process equipment, a new and important factor has to be introduced into the cost calculations. Now, rather than the workman approaching the work area at random or at his will, all operations, even the most simple, must be completely organized. The condition of radioactivity and of unseen danger has posed a problem which has had to be approached with extreme care until considerable information could be accumulated. Now that some of the facts are known and have been recognized, it is possible for personnel to work under conditions of radiation in comparative safety.

Control of Operations

Complete control of every phase of the maintenance operation must be maintained. Nothing can be left to chance or dependence upon the trade knowledge of the individual welder or mechanic that a certain specific operation will be done. All phases and details of the operation must be listed, analyzed and considered in relation to the over-all job. And not the least of these is the radiation survey that precedes, continues during and completes each job.

A radiation monitoring man measures the amount of radiation each worker receives when in an area of possible exposure. Every person entering a controlled area carries small ionization chambers and film badge which can be carried in the lapel pocket. The ionization chambers are read and recorded daily. The film badges are developed every two weeks. These readings are recorded in such a manner as to provide cumulative statistics which assist in determining the effectiveness of the radiation protection program.

When the nature of the work is such that radiation

Fig. 5 Removal of a unit, wrapped in a plastic vinylite sack for protection, from contaminated service

laboratories cannot be provided, the health physicist must assure himself that special ventilation and similar devices will remove dangerous welding fumes to such a low level of concentration in the air that the workers in the area cannot inhale unsafe quantities. Periodic tests are made on each worker who has been in radioactive areas to determine if any radioactive material has been deposited in the body.

Beta-gamma-sensitive and alpha-sensitive instruments are installed at convenient locations so that each worker can be measured for contamination of hands, feet, whole-body, clothing and equipment. These checks are mandatory upon leaving a controlled area.

Emergency procedures have been developed at all installations. Specialists are prepared to cope with any unusual occurrence in the case of emission of significant amounts of radioactive contaminants from reactors or chemical plants. A great deal of research is being done to determine the toxicity of the various radioactive materials and ways in which a person contaminated with them can be successfully treated.

The greatest cause of personnel contamination results from improperly or carelessly-worn protective clothing. In a radiation zone where maintenance work is accomplished, care must be exercised to enforce regulations. Two suits of coveralls, taped-on shoe covers, taped-on rubber gloves and a breathing mask can be uncomfortable and hot. Ordinarily, if a workman's clothing has become disarranged in such a manner that he may become contaminated, the radiation monitoring man will call it to his attention. If a survey should indicate that the workman has become contaminated, he would immediately be taken from the work area. The radiation monitor is ever on the alert for any changes in the radiation level in the work area and will immediately notify the workmen of any change of which they should be made aware.

Typical Maintenance Operations

Figure 1 shows that certain joints to be welded under these difficult conditions are not easily accessible to the welder. However, in such cases the welder has already demonstrated his ability to meet the job conditions on mocked-up assemblies. This obviates the possibility of encountering job conditions which cannot be successfully met.

Figure 2 shows a radiation monitoring man surveying a contaminated area to determine the maximum permissible time which will be allowed the welder. The information he will record is the exposure time permissible and the distance to be observed. Both of these readings are very important, as the mechanic or welder must know how long he can work in the area and how close he can get to the work. Whether or not he forgets this vital information is immaterial, as the timekeeper will inform him when he has reached his exposure limit, at which time he will immediately leave the work area. There is no possibility of "working just a little longer." It is thoroughly understood by each workman that, when he has reached his time limit, he must leave the work area. There is never any argument on this score.

If the radiation level in the work area is high, ordinarily the radiation monitoring man will determine the work interval at the job itself, and then designate an area where the radiation is lower so that the workmen can step out of the work area and into the zone of lower radiation where they may pass tools, relay information, or stand by in case of need. This, then, extends the time which they can assign to the work itself, and without danger to themselves. For example, and to show how important it is that the work area be adequately monitored and surveyed for radiation, one process vessel which was removed from service indicated at a distance of 125 ft a permissible working time of 26 sec. At a distance of 65 ft, the time limit was reduced to 4 sec. Normally, when the initial radiation is so intense, it is not practical to attempt to decontaminate the equipment down to radiation levels where effective work can be done.

When considering welding operations, it is more difficult to do a welding or cutting job at a distance of several feet than it is at a distance of, say, 6 in. This is taken into consideration when setting up exposure time limits for certain welding operations.

Figure 3 shows a welder and a radiation monitoring man ready to approach a radioactive repair job. Such operations are made a matter of complete record so that control of future operations can be developed from this information. Exposure of the individual on any one day is made a matter of permanent record.

A typical sequence of operations for a welding maintenance job would be as follows:

1. A failure in a radioactive process line occurs and a replacement must be welded in.

2. A survey of the work area is made by a Radiation Monitor who establishes the work time limits at certain distances from the work. (These will, in no case, be exceeded by personnel engaged in the maintenance operation.)

3. A decision is made as to which protective clothing must be worn to best protect the individual workmen. (Some of these items are illustrated in the accompanying photographs.) Special Work Permits or Standard Operating Procedures indicate the special clothing which the workmen are to wear in the contaminated work area. One example of what may be required is: All personal clothing is removed, and replaced with (*a*) one pair of coveralls, (*b*) one pair of shoe covers, (*c*) one pair of surgical gloves which are taped to the sleeves of the coveralls, (*d*) one cape-type hood which is tucked underneath, (*e*) another pair of coveralls which are taped to (*f*) rubber boots, (*g*) leather gloves and (*h*) a fresh air or filtration type mask. The type mask depends on the degree and kind of contamination present in the work area.

4. The job is duplicated by a mock-up and the personnel who will do the job are required to rehearse the operation until all details of the job are thoroughly understood by all.

Fig. 6 A remote maintenance job: crane operator is observing in a mirror a pipe to be replaced

5. Meteorological conditions affect the work of bridge builders, linemen, etc. For certain field work on atomic installations, it is necessary to discontinue work if the wind suddenly rises in intensity, in order to prevent spread of contamination.

6. The work area and the equipment to be replaced are decontaminated, where possible, to extend time limits.

7. The defective pipe is removed and prepared for the replacement weld. This may involve portable exhaust hoods and filters to lessen possibility of airborne contamination from fumes.

8. Welding equipment is checked for job adequacy.

9. The job starts and continues until the welder reaches his time limit.

10. The welder is stopped when his time limit is reached. He is required to leave the work area whether or not the job is completed.

11. The welder leaving the job reports conditions as they exist to the next welder on the schedule and makes his recommendations for continuing.

12. The next welder on the work assignment schedule or "team" continues his job.

13. This procedure continues until the welding job is completed.

14. The welding is inspected and tested.

15. The work area is cleaned up and resurveyed to ascertain that all excess radioactive material which resulted from the maintenance operation has been removed.

16. The equipment is put back into service.

17. The individual workmen are surveyed for radioactive contamination as they leave the job. The special clothing which they wore on the job is sent to a special laundry facility. Figure 4 shows a Health Instrument man monitoring a welder who has just completed a repair job that was radioactive. Any unusual conditions of radiation are reported and put on record to assist in developing future procedures which will guard against personnel contamination. If unusual contamination of the welder or mechanic has resulted from the operation, every effort is made to determine what actually happened so that better protective procedures can be developed.

18. Certain equipment used on the job is decontaminated, if possible or practical. Otherwise, it may be kept in controlled zones until the next similar job is encountered.

Special Precautions

It is customary to establish a roped-off area and place radiation zone signs where work is to be done on radioactive process equipment. This serves the dual purpose of preventing unprotected personnel from entering the area and also makes the workmen who are doing the work more conscious of the radiation around them.

If it is necessary to remove equipment from the location for a more thorough decontamination than could be performed there, a plastic vinylite sheeting or bag is sometimes used to cover completely the material or unit, in order that the spread of contamination can be more fully controlled.

Figure 5 illustrates a group of men preparing to remove a unit from contaminated service. It is being wrapped in a plastic vinylite sack for the purpose of transporting it to a location where it can be decontaminated or finally disposed of if decontamination is impossible. This prevents spread of contamination to other areas and restrains it to the plastic covering until it can be removed and sluiced away to the proper containers. It will be noted that two men are standing by as replacements for any of the men working who may exceed their work time limit. Having workmen available even though they may not actually be engaged in the work itself is very costly.

Planning Operations

When maintenance work is urgently required and time limit is short (limited to a few minutes in certain instances), it is necessary to provide a number of standby mechanics and/or welders to carry on after the man working has exceeded his time limit. If the work is of considerable extent, it will be readily seen that the labor cost for such operations would be regarded as excessive under normal industrial maintenance conditions. When work of such nature must be done, the workmen are generally organized in groups and briefed so that better cooperation can be obtained. It should be obvious that, when such large crews are required, other maintenance operations are affected because of the need for withdrawing personnel from other locations or plants. Under such conditions, a number of people may receive their daily or weekly permissible radiation exposure. The workmen, having

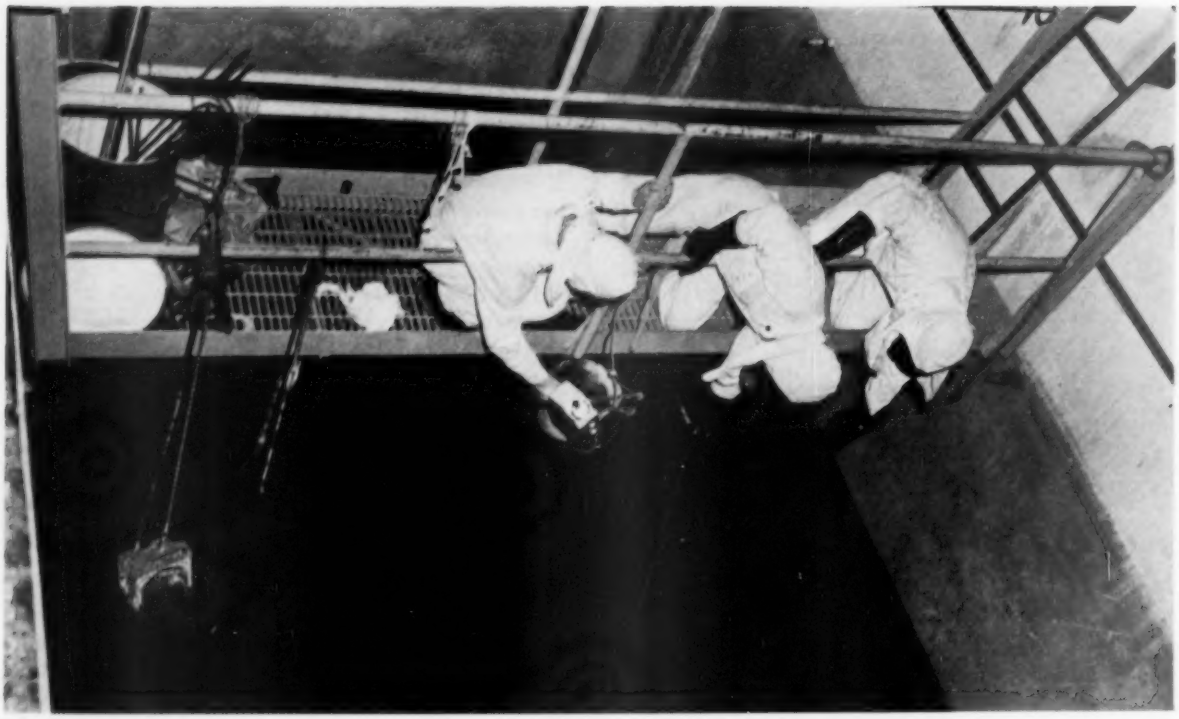


Fig. 7 Workmen replacing a gasket in a pipe connection under several feet of water while another man surveys work area for radiation

received their permissible exposure, must work in nonradioactive zones for the rest of the week. Thus, planning and scheduling work becomes of the utmost importance.

To expedite certain work, it has been necessary to partially decontaminate certain items of equipment, and then, by use of long electrode holders using cutting electrodes or long cutting torches, to remove certain vital or difficult-to-replace components from the equipment. These removed sections are ordinarily small enough to be successfully decontaminated and can then be used to refabricate a spare item of equipment. Removal of such sections is usually critical as to time limits, and every effort is extended to assist the welder to accomplish as much as possible within the short work interval allotted him. A misunderstanding or error in judgment at such a time may seriously interfere with the fore-planned sequence of operations.

Very often the ground or floor or equipment underneath the welding operation will be covered with protective material which can be removed later. This avoids additional contamination of surrounding material or equipment.

After all work is completed and all work debris is removed and taken away for disposal, the Radiation Monitor will make final survey of the area. The special radiation signs can then be taken down and the ropes removed from the work area, signifying that the condition is again normal. If any contamination is found, it would be removed before the roped-off area was declared clean.

Fig. 8 Typical breathing mask being held by a welder

Remote Maintenance Jobs

Figure 6 is an illustration of a remote maintenance job. The crane operator is observing in a mirror the pipe to be replaced. Some piping that has been in service is so radioactive that extensive decontamination procedures must be accomplished before it would be practical even to consider repair of the failed unit. Periscope and mirror work is common and inherent to some remote maintenance work but has not been too successful in welding and cutting operations in the field. It is believed that much development work should be done in this area and that it will eventually be practical to weld and cut by remote means.

Figure 7 shows two workmen replacing a gasket in a pipe connection under several feet of water while another man surveys the work area for radiation. While this is mechanical work, it is illustrative of the way cutting jobs are done under water. The purpose of water immersion is to protect the workmen against the intense radiation emanating from the job being worked on. Even for such work, there are work time limits, as it is seldom practical to work on such items under enough water to shield off completely all radiation. Such jobs are difficult. Vision is impaired and tools are difficuilt to control at a distance of several feet from the work. Complete cooperation between personnel is essential at such times, and infinite patience is essential to do such jobs successfully.

Figure 8 illustrates a welder holding a breathing mask and gives an idea of the encumbrance which such a device may be to doing a workmanlike job under difficult conditions.

Fig. 9 Metal-arc welding a stainless steel pipe joint in a radiation area

Figure 9 shows a welder using the shielded-metal arc process to weld a stainless steel pipe joint. It will be observed that he is in the normal position and apparently well at ease doing this job. There is no reason for hurrying on such a job. If the welder understands the conditions, has rehearsed the operations sufficiently to be well conversant with them, and is confident of his ability to meet job conditions, there is no reason why the repair job should not be completed successfully. If the welder has had a few sad experiences in not being properly prepared for certain operations, he will be doubly certain that all contingencies, at least in so far as he is concerned, will have been taken into consideration.

Welding and Cutting Procedures

Standard welding and cutting procedures can be used when working under radiation controls. The only difference is that local conditions may make it necessary that extensions must sometimes be used on cutting torch or electrode holders or inert arc torches. Also, greater attention must be given to absolute

Fig. 10 Welding actually in process under Special Work Permit conditions

precision of technique and procedure, as the schedule may not tolerate a failure to make a satisfactory weld. Such an occurrence might adversely affect production schedules and have any number of repercussions later on. Our maintenance welders are continually making suggestions to improve our approach to this situation. There is no fear of radiation among the people who have worked with it and our welders accept the adverse conditions under which these operations must be performed. Some consideration must be given during cutting operations that the slag from the cutting operations will be restrained from going outside the work area. These operations are ordinarily performed on stainless steel, so it is customary to use cutting electrodes, flux-injection or iron-powder cutting for such work. It is not necessary to use exhaust units when the inert arc process is being used, but in certain locations, the other processes require that the fumes be collected and passed through a disposable filter.

Protective Clothing and Equipment

Welding clothing is not too comfortable at best, and it is now necessary to add in addition other equipment and clothing in order to safeguard the welder against contamination. It is believed that improvements could be made in this direction. The welder should be as comfortable as possible in order to make him effective at his assigned task. Equipment manufacturers might possibly develop clothing which would better serve the triple purpose of protecting the wearer against thermal radiation, hot metal from the welding operation and radiation from the equipment on which the work is being done. At present, the welder must wear the normal protective clothing used by all persons in a contaminated area and, in addition, leather gloves, jackets and coveralls if he is using a welding or cutting process which expels molten metal from the weld area itself. It might be possible to provide some garment which would offer adequate protection against these conditions.

Figure 10 shows welding actually in progress under Special Work Permit conditions. This welder is wearing two pairs of coveralls, shoe covers, rubbers over the shoe covers, surgical gloves under the outside rubber gauntlets, cloth hood and fresh-air mask. The inner pair of coveralls is taped to the surgical gloves and to the shoe covering to prevent accidental entry of contaminating material. The fresh-air mask must be worn from the time the welder prepares to enter the work area until he finally leaves and is surveyed for contamination.

The type of mask worn is governed by the kind of particulate matter and not by the level of radiation. Assault masks, self-contained breathing apparatus and fresh-air masks are worn, the choice depending upon the work to be done. The fresh-air masks may be serviced from cylinders, or by fresh-air line from outside the work area.

Oxy-acetylene cutting and welding equipment now available is, in the main, satisfactory with the exception that more readily operable valves would be helpful. When the welder must wear a pair of rubber gloves, plus leather gloves, the manipulation of small valve heads or handles becomes rather difficult. It is believed that special handles could be developed that would immensely improve this apparatus for work under radiation control conditions.

Welding equipment should be developed which is pointed toward this specific type of maintenance welding operation. Welding hoods which could be removed without interfering with the breathing equipment would be helpful. Conventional equipment, it is believed, could be redesigned for greater comfort. For certain purposes, it is convenient to have breathing equipment and welding filter lens-holding apparatus combined, but it is believed that a greater variety of combinations of such devices should be provided so that the welder can be at greater ease while he is engaged in the welding or cutting operation and as he is standing by while the mechanics are aligning the work or otherwise engaged. Portable fume exhaust equipment which could itself be easily decontaminated would be very helpful. It is essential that welding fumes from equipment that is quite radioactive be controlled, as the air-borne particles may carry contamination to other equipment or contaminate the workers themselves. In certain instances, only one attempt may be made to repair the failed unit.

There appears to be little question that, as welding technology increases, methods of welding and cutting by remote control will be developed. There is great need at the present time for such devices, but none have been developed that are usable outside the laboratory.

Although certain devices are available for the remote control of arc-welding generators, it is believed that such devices could be developed which would be more suitable for working under radiation control conditions. Present practice depends mostly on signals relayed between welder and helper to change welding machine settings. This is irritating and time-consuming. However, unless remote-control equipment is available, there is no recourse except to adjust the machine setting through relayed signals.

Conclusions

A correlation of experience as the atomic industry develops is needed so that all can benefit from the data that have been accumulated since maintenance of atomic facilities became a necessity.

A big and an important challenge to industry is offered by this situation. To measure up to the demands will be a big job. It is hoped that the problems involved will be adequately considered.

Acknowledgments

The authors wish to acknowledge the helpful suggestions offered and assistance given by C. R. Brewer, K. K. Campbell, M. L. Mickelson, M. G. Peterson, O. C. Schroeder, J. M. Smith Jr. and R. E. Toczek, all of the General Electric Co. Hanford Atomic Products Operation, Richland, Wash.

Fig. 1 Plate girder bridge over the Spring River, Highway 62, Hardy, Ark.

FABRICATION OF BRIDGE PLATE GIRDERS BY SUBMERGED ARC WELDING

By JOSEPH H. HOFFMAN

Less shrinkage and distortion, high rate of welding speed, uniformity and high quality of weld lead to the use of tandem submerged arc welding for fabrication of bridge plate girders

ABSTRACT. This paper describes the method of fabricating a 120-ft, 6-in. welded plate girder bridge span starting with the cutting to size of the plates, the jigs used for fitting and welding, the welding procedure using the tandem submerged-arc-welding process, shop changes to welding machine carriage to suit welding conditions and loading for shipment.

The details bring out the reasons for using the described jigs and fixtures, the difficulties encountered due to welding distortion and how they were overcome, and why the tandem submerged-arc-welding process was used instead of others.

In this age where welding is taking over many jobs that formerly were riveted, the author hopes this article will bring out many comments and new ideas from the "welding fraternity."

Introduction

The first all-welded bridge in America is reported to be a 135-ft skew truss span built in Chicopee Falls, Mass., in the year of 1927. Incidentally, this bridge is still in use.

Joseph H. Hoffman is Assistant Superintendent of the Fabricating Division of Bethlehem Steel's Beaumont Yard, Beaumont, Tex.

Presented at the AWS National Spring Meeting held in Kansas City, Mo., June 7–10, 1955.

Since that humble beginning in 1927, during the bare electrode days, many technical advances have been made in the art of welding, such as covered electrodes, submerged arc welding and, lately, submerged arc welding with multiple electrodes. Design engineers have kept pace with these developments; hence, more and more bridges are now welded structures, instead of riveted.

The biggest reasons for designing welded plate girder bridges are: (1) the saving in the amount of steel needed to do the job. (2) Curved lines can be readily used to advantage in varying depth girders, thereby eliminating sharp corners and breaks in stress paths.

The bridge shown in Fig. 1 is over the Spring River on Route 62 at Hardy, Sharp County, Arkansas. The bridge was built to the Arkansas State Highway Commission Standard Specifications for Road and Bridge Construction and the AMERICAN WELDING SOCIETY Standard Specifications for Welding Highway

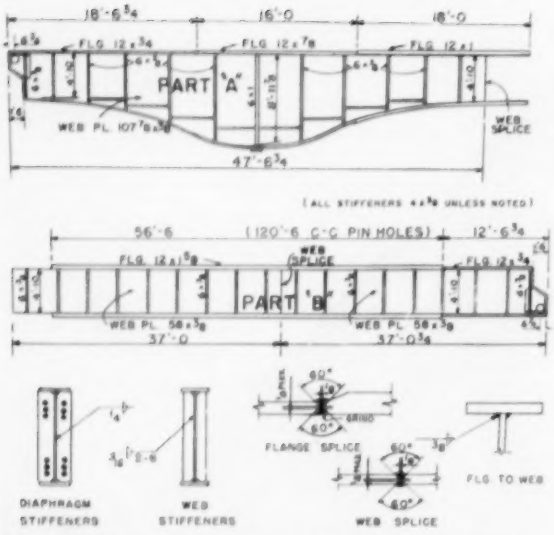


Fig. 2 Principal dimensions of 120-ft 6-in. plate girder

and Railroad Bridges. Shop inspection was by the Arkansas State Highway Department.

The steel used in the plate girders and WF beams met the Arkansas State Highway Department special provision 807-21, Structure Steel for Bridges, dated June 7, 1954. This specification is essentially the same as ASTM-A-373, dated Mar. 31, 1954, and is now being specified on many welded bridge jobs in lieu of ASTM A-7. The main difference between ASTM-A-373 and ASTM A-7 is that more emphasis is placed on the chemical properties of A-373, instead of the mechanical properties, with the carbon content being controlled to facilitate easier and more uniform welding.

The over-all length of the bridge in 1076 ft. There are 11 spans, each span having four main members. Three of the spans are made up of wide flange beams; the other eight are plate girders.

One of the plate girder spans is 75 ft long by 5 ft deep. Six of the spans are 120 ft 6 in. long and the last span is 123 ft long. These last seven spans are 5 ft deep, except at the piers where they are 9 ft deep.

For the purpose of simplicity and to avoid duplication, the fabrication and welding of one of the 120-ft, 6-in. girders is hereby described.

The over-all length is 121 ft $7^1/_2$ in., with a measurement between centers of connecting pinholes of 120 ft 6 in. The flanges are all 12 in. wide, with varying thicknesses ranging from $^3/_4$ to $1^5/_8$ in. The break in thickness occurs at the same point on top and bottom flanges. The web is $^3/_8$ in. thick and 4 ft 10 in. wide, except where it increases to 8 ft $11^7/_8$ in. at the pier. The stiffeners are 6 x $^3/_8$ in. in the deep part of girders and where the diaphragms frame in, with the exception of over the bearing plate where they are 6 x 1 in. The

Fig. 3 Fitting of Part A or curved section of plate girder in horizontal jig

remainder, including the horizontal stiffener bars in the curved part, are all 4 × $^{3}/_{8}$ in. Two $^{13}/_{16}$-in. doubler plates are used at each end to give added strength where holes are drilled for connecting pins.

Fitting—First Stage

It was decided to fabricate and weld the girder in two separate parts (Fig. 2), then join the two parts to make a complete girder.

The web of Part A, consisting of a single plate 47 ft 8 in. long by 9 ft 1 in. wide, was first laid out with lines for cutting and stiffener bars. Angles were bent to the exact curves called for and were used as a track for cutting the web by a short wheel-base oxy-acetylene portable machine. While the curved side was being cut, the straight side was also cut.

The top flange, consisting of three pieces with different thicknesses, was beveled for butt welding, welded and the weld ground flush with plate for joining to the web. The bottom flange, also consisting of three pieces with different thicknesses, was first beveled and then rolled to the proper radii, but not welded together until fitted to the web. A jig was made so that the web plate was supported in a horizontal position approximately six inches off the floor. This enabled the two flanges to be placed vertically with one edge on the floor along both longitudinal edges of the web, then fitted and tack welded together (Fig. 3, foreground). Temporary braces were tacked from the edge of flange to web about every three feet, top and bottom on one side only, to keep the flanges perpendicular to web and give added support while moving to welding area. Additional experience showed that the number of these braces could be reduced and this was subsequently done.

Unlike Part A, Part B was assembled in a vertical position (Fig. 4), with the aid of specially made fit-up stands (Fig. 5). The web section consisted of two plates 37 ft 2 in. long by 59 in. wide that were cut to size on a flame planer, then butt welded, after which the layout men took over to locate stiffeners, etc. The flanges were beveled, welded and ground flush. The thick $1^{5}/_{8}$-in. flanges were ground in way of the web as experience showed that the mill scale (thick plates generally have more mill scale than thin plates) interfered with the welding, causing some pinholes. Fit-up stop angles were tacked to bottom flange about every six feet, toed to the outside, and with the back of the vertical leg $^{3}/_{16}$ in. (half of web thickness), from the centerline. The bottom flange was placed in four fit-up stands, the web put on flange and the loose plates on top of fit-up stand bolted in place. Additional fit-up angles were tacked to the flange on the other side of the centerline about $^{3}/_{4}$ in. from the web and directly opposite the first set. Wedges were driven between

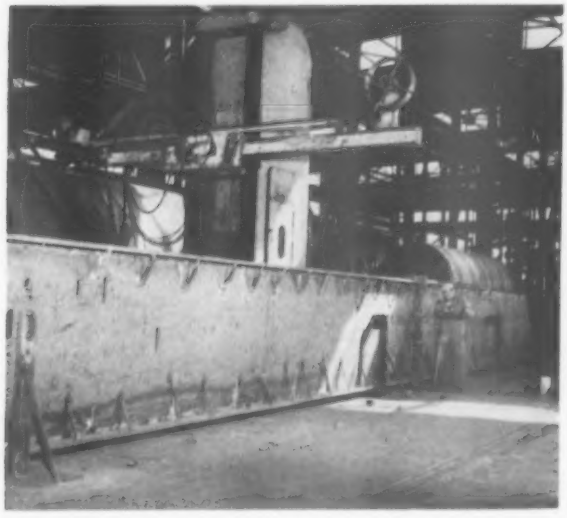


Fig. 4 Fitting of Part B in fit-up stands; note workman pulling top flange tight against web by turnbuckle attached to notched plates

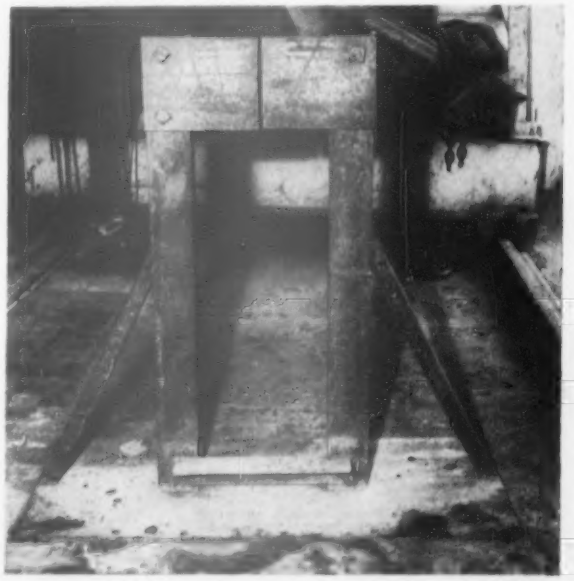


Fig. 5 Close-up of fit-up stand with bolted plates to hold web in place

these angles and the web to place the web against the stop angles along the centerline. Wedges were also driven between shop floor and flange, then web was tack welded on both sides to the flange. Temporary braces were tacked on one side from edge of flange to web and, just as in Part A, the number of braces was later reduced. Both sets of fit-up angles were first tacked on the top flange, the flange placed on the web, fitted and tacked together, then temporary braces added. In order to insure a tight fit between flange and web, turnbuckles attached to notched plates with the top and bottom flanges in the notches were used (Fig. 4).

Welding—Submerged Arc

The joining of the web and flange called for a $^{3}/_{8}$-in. fillet weld. The best way known to the shop to deposit this much metal in one pass was by the submerged arc

Fig. 6 Submerged arc welding of Part A with welding machine riding on tilted web. Note the C bars and wedges to hold flange straight

method with the work positioned so that the weld would be at the bottom of a hog trough or flat fillet. Inasmuch as the relatively new two-wire submerged-arc welding machine could be run at two plus times the speed of a single wire machine, this method was chosen.

The girder assembly was placed against a 36-in. I beam with the web at about a 35-deg angle from the floor and the temporary braces on the bottom side (Fig. 6).

C bars were slipped over the flange about every four feet and a wedge driven between the inside of bar and flange. Whereas the temporary braces mentioned earlier were to keep the flange square with the web, the C bars were to restrain the flange while the weld cooled, thereby keeping it straight.

The submerged-arc equipment used was a multiple arc welding machine powered by two 1000-amp transformers in parallel. Two $^{5}/_{32}$-in. diam filler wires spaced $^{3}/_{8}$ in. apart were used in a tandem position. The welding composition or flux was a commercial composition grade no. 50, size 8 x 48.

Changes to Welding Carriage

The following changes were made to the moving carriage or "mule" so that it would run the full length of the girder assembly along the 35-deg tilted web (Figs. 7 and 8):

1. Two extra wheels were added 90 deg from bottom wheels, one at front end of the "mule" and the other at back end, to ride along the flange.
2. A rack was added to the side opposite the extra

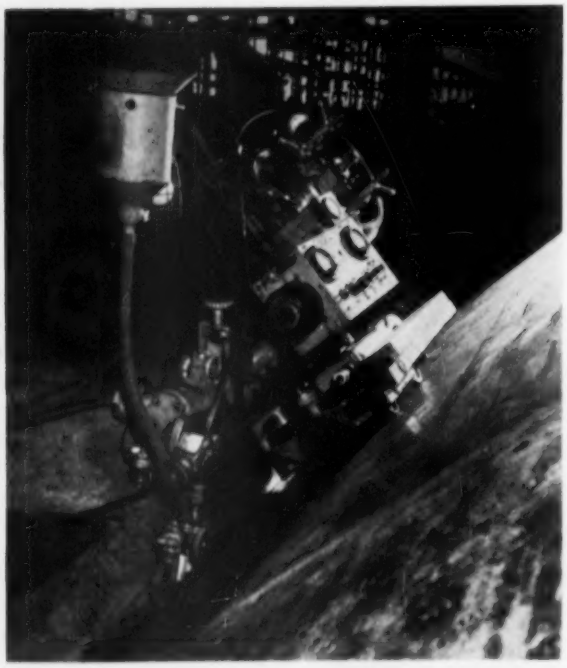


Fig. 7 Two wire submerged arc welding machine in welding position. Note the recessed guide wheel and counterweights to offset the weight of wire coils that are off center due to tilted girder

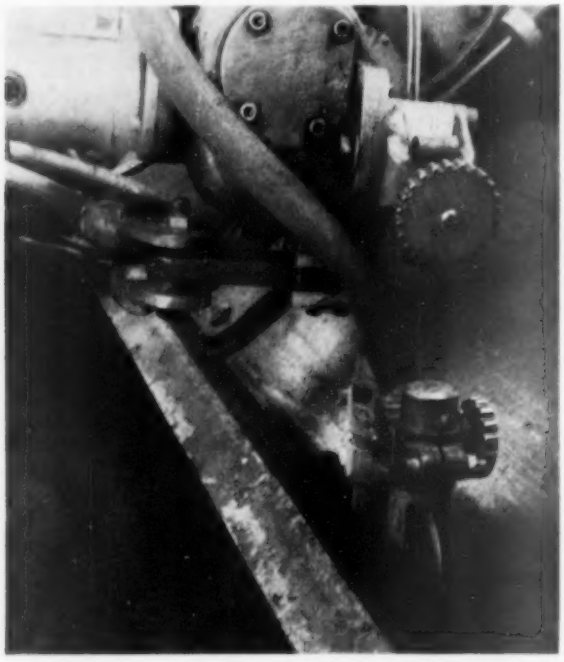


Fig. 8 Close-up of welding head assembly showing the recessed guide wheel and one of the added wheels to ride along the flange

wheels to hold counterweights to offset the weight of the two coils of wire which are off center due to angle of machine on tilted girder.

3. A guide wheel was added to the welding head to ride in the hog trough preceding the flux tube and welding wires. The face of the wheel was recessed like a crane wheel so that the fit-up tacks would interfere as little as possible when the wheel passed over them.

Welding Difficulties

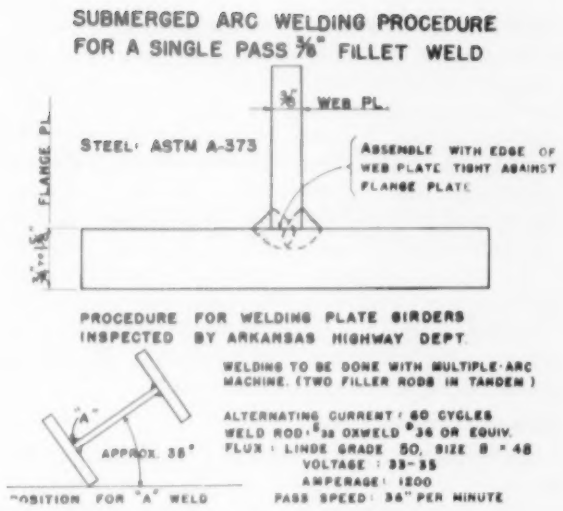
Some minor welding difficulties were encountered and the following steps were taken to correct them:

1. A tight fit between web and flange was absolutely necessary or a burn-through would result due to the high heat and fluid weld puddle. A little extra care in fitting and the use of wedges and turnbuckles previously described solved the problem.

2. Pinholes showed up in weld if there was excessive mill scale, or if moisture had collected in the joint between the time of fitting and welding. The thick flanges had the mill scale ground off and the grade no. 50 welding composition or flux was used. Preheating ahead of the weld dried any moisture that might have collected.

The first weld was made the full length of the girder assembly at about the following conditions (Fig. 9): Speed, 36 ipm; volts, 35; amperes, 1200.

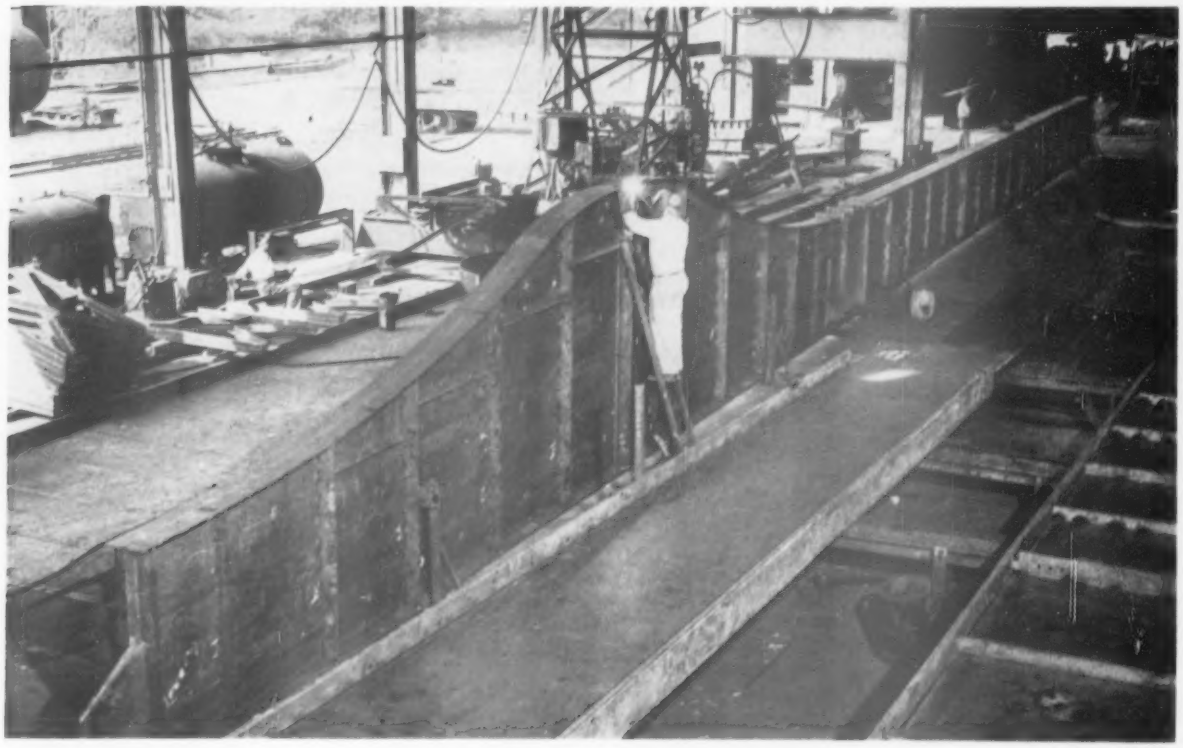
The girder assembly was then placed on the other side of the beam rest, the temporary braces were taken off, the welding machine was put in place and welding started from the end where the first weld had finished. This procedure was duplicated to weld the other flange and web joint on Part B, while the curved part of Part A was welded by hand in the following manner.


SUBMERGED ARC WELDING PROCEDURE
FOR A SINGLE PASS 3/8" FILLET WELD
WEB PL.
FLANGE PL.
STEEL: ASTM A-373
ASSEMBLE WITH EDGE OF WEB PLATE TIGHT AGAINST FLANGE PLATE
PROCEDURE FOR WELDING PLATE GIRDERS INSPECTED BY ARKANSAS HIGHWAY DEPT.
WELDING TO BE DONE WITH MULTIPLE-ARC MACHINE. (TWO FILLER RODS IN TANDEM)
ALTERNATING CURRENT: 60 CYCLES
WELD ROD: 5/32 OXWELD 36 OR EQUIV.
FLUX: LINDE GRADE 50, SIZE 8 × 48
VOLTAGE: 33-35
AMPERAGE: 1200
PASS SPEED: 36" PER MINUTE
"A"
APPROX. 38°
POSITION FOR "A" WELD
Fig. 9 Submerged arc welding procedure

Welding of Curved Section—Shielded Arc

Girder assembly A was placed with the web hori-

Fig. 10 The final weld being made on rocker plate of upside-down completed 120-ft 6-in. girder



zontal for the welding of web and flange joint on curved section by hand. A 20-in. stringer bead was first put in on 40-in. centers on one side. The assembly was then turned over and the process repeated, but with the weld opposite the open space on the other side of web. The open spaces were next welded, making a full stringer bead on that side. Once again the assembly was turned over and the open spaces on the first side welded to make another continuous stringer bead. The same process was repeated on both sides with the second bead making up a full $^{3}/_{8}$-in. fillet. One might perhaps say the procedure involved a lot of positioning. It did, but not one of the girders was crooked when this procedure was used.

Fitting—Second Stage

The girder assembly was put in a horizontal position for the installation of all the stiffener bars and the doubler plate on one side. The stiffeners, which were purposely cut a little long, were ground on each end to bear on the top and bottom flanges and tacked in place. All welding on the bars, whether continuous or intermittent, was done by the skip method, first on one side of bar then on the other, with the final weld being made to the flanges. The girder assembly was again turned over and the process repeated.

The next step involved taking final over-all measurements for the drilling of connecting pinholes and trimming to size of the ends to be joined to make a complete girder.

Final Assembly

Parts A and B were placed upside down in five fit-up stands and fitted together for welding (Fig. 10). The joint between the two web plates was welded first, the web to flange joints next and last were the two flange-to-flange joints. After the addition of the rocker plate, the completed girder was ready for painting.

Shipping

The length of the girders required shipping by a bolster load on three flat cars (Fig. 11). Four girders, making up one span, were loaded upside-down on steel bolsters which were, in turn, connected to the outside girders by plates, angles and tie rods. The four girders were tied together by bolted plates top and bottom. Prior arrangements were made with the steel erector and railroads, after unloading at the job site, to ship the same cars with the bolsters and rigging back to the shop for reloading. Four sets of cars, equipped with bolsters, were shuttled back and forth during the shipping.

Conclusion

The most difficult factor to control in welded construction is the shrinkage and distortion caused by the welding itself.

During the fabrication of the plate girders this shrinkage and distortion was kept in check by means of braces and clamps plus staggered intermittent welding sequences where manual shielded arc welding was used. The tandem submerged arc welding had less shrinkage and distortion than shielded arc welding and, because of the high rate of welding speed, uniformity and high quality of weld, it seems to be the answer to this type of fabrication.

Acknowledgments

The author wishes to thank the management of Bethlehem Steel Co., Shipbuilding Division, Beaumont, Tex., for permission to print this material and the many fellow employees who helped prepare it; the erection contractor, D. F. Jones Construction Co., Little Rock, Ark., for their full cooperation during the contract; the Arkansas State Highway Department for furnishing the erected bridge picture and the following: Herbert Eldridge, Director of Highways, Arkansas State Highway Dept.; Ward Goodman, Bridge Design Engineer, Arkansas State Highway Dept.; L. A. McCain, Asst. Construction Engineer, Arkansas State Highway Dept.; P. V. Pennybacker, Special Bridge Engineer, Texas State Highway Dept.

Bibliography

1. Welding Handbook, Third Edition, American Welding Society, 1950.
2. Morgan, Nathan W., "Development of Welded Bridge Construction," The Welding Journal, 32 (10), 923-927 (1953).

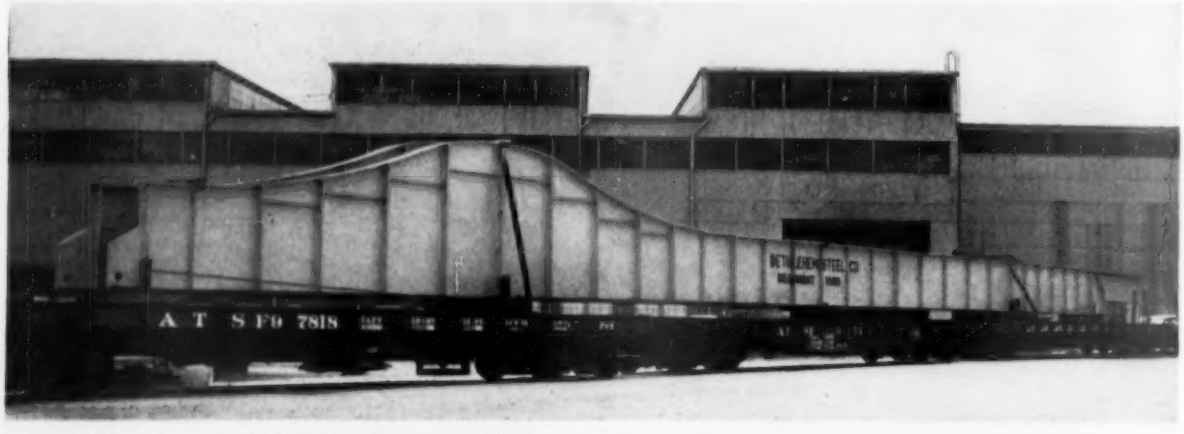


Fig. 11 Four girders loaded on three flat cars ready for shipment

JOINT DETAIL FOR INERT ARC WELDING OF PRESSURE PIPING

Author outlines technique wherein proper preparation of root edges of joint produces satisfactory uniform inside bead conditions in all positions

By R. T. PURSELL

Inert arc welding of pressure piping

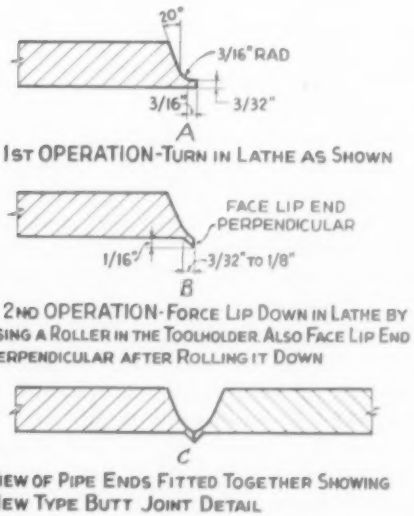

20°
3/16" RAD
3/16"
3/32"
A
1ST OPERATION-TURN IN LATHE AS SHOWN
FACE LIP END PERPENDICULAR
1/16"
3/32" TO 1/8"
B
2ND OPERATION-FORCE LIP DOWN IN LATHE BY USING A ROLLER IN THE TOOLHOLDER. ALSO FACE LIP END PERPENDICULAR AFTER ROLLING IT DOWN
C
VIEW OF PIPE ENDS FITTED TOGETHER SHOWING NEW TYPE BUTT JOINT DETAIL

Fig. 1 Novel manner of preparing the root edges of the joint for this welding procedure

Introduction

The application of the inert-gas-shielded arc-welding process for the purpose of eliminating metallic backing rings or inserts in the welding of circumferential butt joints in pressure piping systems has stimulated considerable interest in the past few years. Many of the country's leading welding engineers and metallurgists have been experimenting with various techniques involving this process, with the sole purpose of developing a technique that will produce desirable results consistently and economically.

As in all forms of development work, problems of varying magnitudes are encountered. The major problem confronting those engaged in applying this process to pressure piping work is that of producing a uniform inside bead condition consistently in all positions. A technique which will produce satisfactory results without the use of metallic inserts or other types of backing materials is, of course, desirable. The data presented herein outline such a technique recently developed by the author.

Technique

The major feature of this technique is the novel manner of preparing the root edges of the joint. Figure 1 illustrates the welded joint detail employed in the development of this welding procedure. This same joint detail was used by the author over 12 years ago, and has recently been revived and used with marked success in conjunction with the inert-gas-shielded arc-welding process.

This method of preparing the joint produces an internal circumferential lip, similar to an insert or backing ring. When the root edges of this type of joint are fused together in an inert gas atmosphere, the inevitable concave inside condition, generally prevalent when welding in the overhead position, is eliminated. The $^{3}/_{32}$ in. thickness of the lip affords the necessary extra material during fusion to produce

R. T. Pursell is the metallurgical engineer with Stone & Webster Engineering Corp., Boston, Mass.

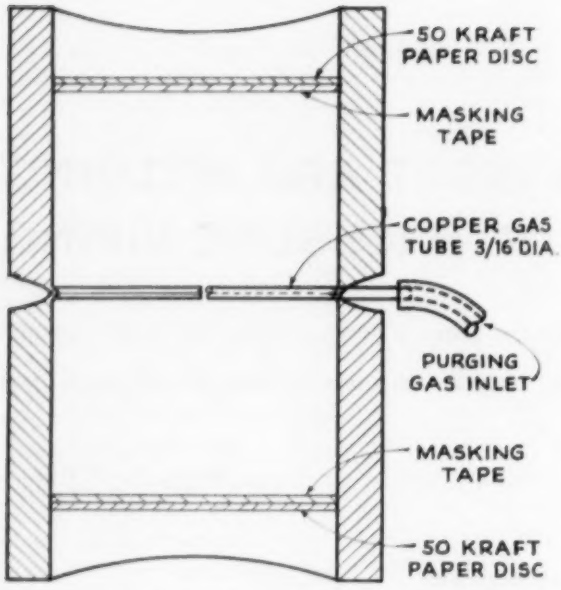


Fig. 2 Method used for inserting and retaining backing gas during inert arc welding of first two beads

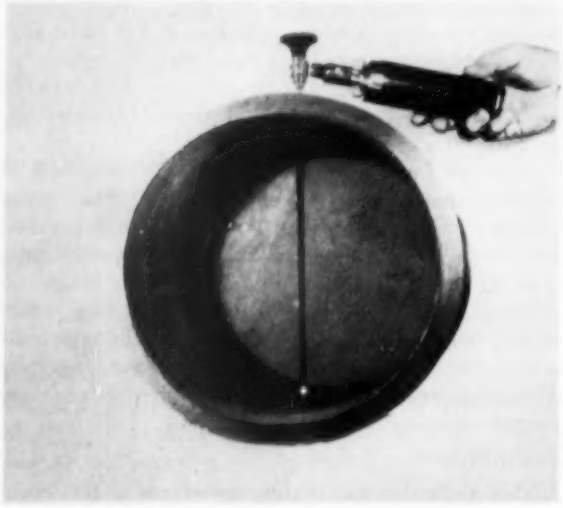


Fig. 3 Method of using Borescope for internal inspection

uniform inside conditions, and it also reduces the tendency of burning through during the initial fusion of the root edges of the joint. Therefore, a desirable, uniform, internal root bead can be consistently obtained in any position.

Procedure

In this welding procedure, two inert-gas-shielded arc-root beads are deposited manually, employing an internal inert gas backing, as shown in Fig. 2. The second bead is deposited using a $^1/_8$ - in. diam filler rod, and the rate at which this bead is applied has a great bearing on the inside contour of the weld. The inside

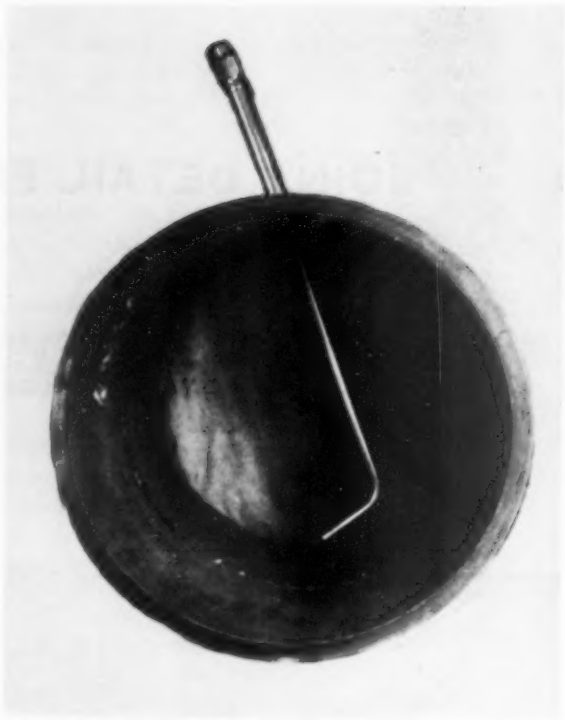


Fig. 4 Method of using oxy-acetylene flame for burning out paper dams

condition of the root weld is conveniently and adequately inspected prior to subsequent welding by using a Borescope, as illustrated in Fig. 3. This method of inspection at this stage of the procedure makes it possible to rectify any objectionable internal defects by re-fusing such areas and reinspecting prior to depositing the remainder of the weld.

The paper dams used to retain the internal gas in the area of the joint are burned up during the stress-relieving operation. When stress relieving is not required, the paper dams are burned up with an oxy-acetylene flame by attaching a special tip to an oxy-acetylene torch and inserting it through the gas inlet hole, as shown in Fig. 4.

After the two root beads are deposited, using the inert-gas-shielded arc method, the subsequent welding may be performed by employing the manual electric metallic arc welding method, the inert-gas-shielded arc automatic welding method, or the submerged-arc automatic welding method. In this paper, the submerged-arc automatic welding method will be described and illustrated, as applied to field shop fabrication. A fixture was designed and built to accommodate a submerged arc, portable, flexible welding head, thus converting it into an automatic welding unit, as shown in Fig. 5. Adjustments were installed for vertical movement of the head in order to provide for varying diameters, as well as in the horizontal plane parallel to the pipe to accommodate the stringer bead technique of depositing the weld.

Fig. 5 Welding fixture used for submerged arc welding

A welding technique for chrome-molybdenum piping is outlined in Table 1. After the completion of the inert-gas-shielded arc welding, the submerged arc welding is started with a preheat obtained with an oxy-acetylene flame of between 150 and 200° F. Because the submerged arc weld is continuous from start to finish, the heat input from welding is sufficient to maintain a suitable preheat temperature without the necessity of applying heat from an outside source. For example, starting with no preheat at all, and after depositing 4 or 5 beads, the temperature in the preheat area will reach approximately 250 ° F, and at the completion of a weld requiring 20 to 25 beads, the temperature will be between 500 and 600° F.

The submerged arc weld is applied as a two-man operation; one man operates the welding head and the other man cleans off the flux during the welding operation.

Stress relieving is accomplished using preformed, clamp type, copper induction heating coils without water cooling, as shown in Fig. 6. These coils are hinged so that they open and close like a jaw; consequently, no wrapping is required. By mounting the coils in a permanent fixture, the welded assembly can be readily set up and removed. In order to take advantage of the residual welding heat (500–600° F) at the completion of the weld, the welded assembly is immediately placed in the coils and stress relieved at 1325 ± 25° F; such a procedure makes it possible to realize a considerable saving in the stress relieving operation.

Table 1—Welding Technique for Chrome-Moly Piping

TYPE OF JOINT: SINGLE U-BUTT JOINT

INERT GAS SHIELDED ARC WELDING TECHNIQUE

BEADS	FILLER ROD	*TUNGS'N ELECTR'DE	**GAS CUP	WELDG GAS ARGON CFH	PURG'G GAS ARGON CFH	DC STR POL I	DC STR POL V
1	NONE	3/32	5L	15	5	120-140	10-14
2	1/8	3/32	5L	15	5	140-150	10-14

*THORIATED TUNGSTEN **METAL CUP, LONG NECK

SUBMERGED ARC WELDING TECHNIQUE

T	FILLER ROD	BEADS	D.C. – REV. POL. AMPS	VOLTS	WELDING SPEED IPM – AVERAGE
1/2	3/32	10	175 - 225	28-32	10 - 15
5/8	"	12	175 - 225	28-32	10 - 15
3/4	"	14	175 - 225	28-32	10 - 15
7/8	"	16	200 - 250	30-34	10 - 15
1	"	20	200 - 250	30-34	10 - 15
1 1/8	"	25	200 - 250	30-34	10 - 15
1 1/4	"	30	200 - 275	32-35	10 - 15
1 1/2	"	32	200 - 275	32-35	10 - 15
1 5/8	"	35	200 - 300	32-36	10 - 15
1 3/4	"	40	200 - 300	32-36	8 - 15
2	"	50	200 - 300	32-36	8 - 15

NOTES: THE NUMBER OF BEADS REQUIRED MAY VARY SLIGHTLY, THOSE GIVEN IN THE TABLE REPRESENT AN AVERAGE.

THE WELDING AMPERAGE, VOLTAGE AND SPEED WILL VARY BETWEEN THE FIRST TWO OR THREE BEADS AND THE REINFORCEMENT BEADS IN ORDER TO OBTAIN DESIRABLE RESULTS.

The photographs in Figs. 5 and 6 were taken at a field fabricating shop where pipe fabrication is being performed for a steam generating station (100,000-kw

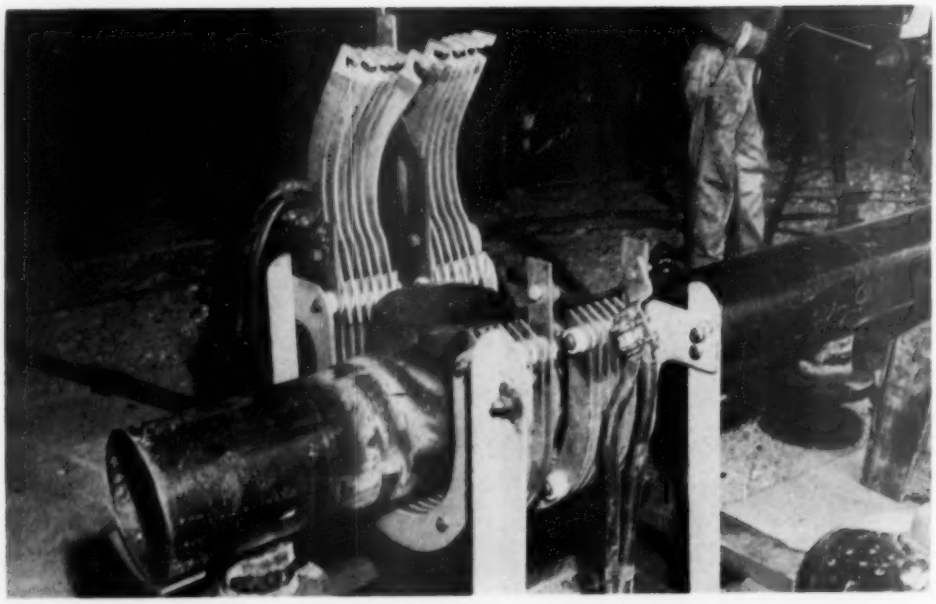


Fig. 6 Clamp type induction heating coils

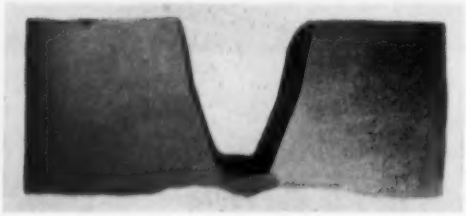


Fig. 7A Cross section macro-specimen showing root bead contour

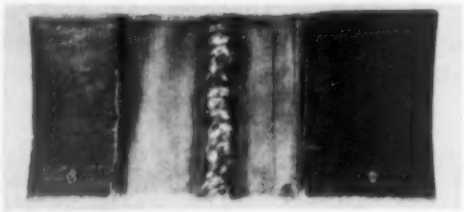


Fig. 7B Macro-photograph of inside bead condition

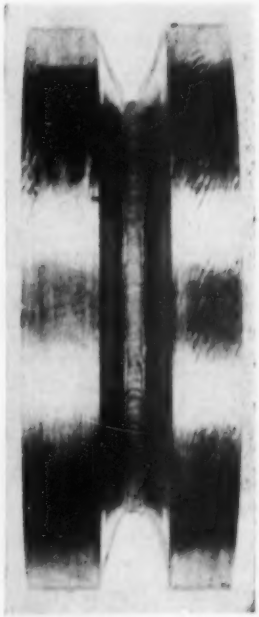


Fig. 8A First bead of inert arc weld in groove

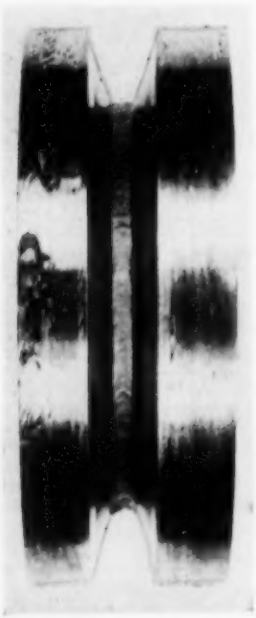


Fig. 8B Second bead of inert arc weld in groove

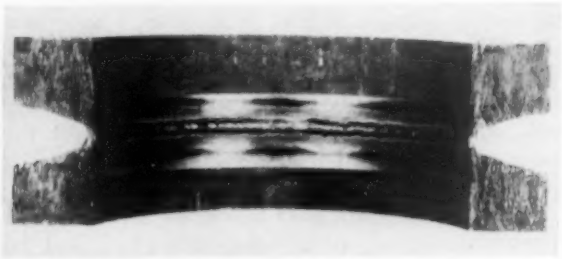


Fig. 9 Inside bead condition

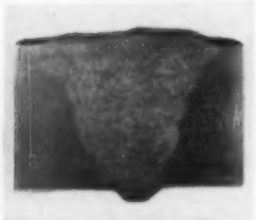


Fig. 10A Cross section macro-specimen of finished weld

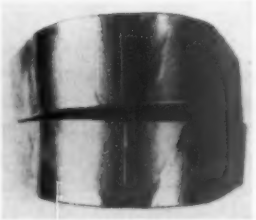


Fig. 10B Side bend specimens of finished weld

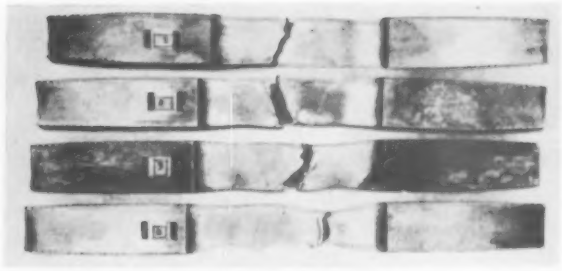


Fig. 11 Reduced section tensile specimens

Fig. 12 Finished weld, note smooth submerged arc welding beads and the uniform condition of the inside

unit). The joint detail and the inert-gas-shielded arc welding are the same for shop fabrication and field erection.

Tests and Observations

A great many tests were made, including cross-section macro specimens, guided side bends, tensile tests and radiographs. The observations of these tests reveal that satisfactory results can be accomplished readily and consistently in field shop fabrication and field erection of pressure piping. The materials used in these tests were 10-in. diam P11 Schedule 120 and 10-in. diam P22 Schedule 160.

Although it has not been discussed in this paper, satisfactory results have been obtained with this type of joint detail on the following piping materials: 18–8 stainless steel, Inconel, Incoloy, copper, aluminum and mild carbon steel.

Figure 7*A* is a cross-section macrospecimen, illustrating the contour of the two inert-gas-shielded arc-welding beads as deposited; Fig. 7*B* is a photograph of the inside surface condition of the same sample.

Fig. 13 Radiograph of completed weld—radiographically sound

Figure 8*A* is a photograph showing the outside appearance of the initial root bead and Fig. 8*B* illustrates the appearance of the second root bead, both beads as welded with the inert-gas-shielded arc method.

Figure 9 is a photograph showing the inside condition after the two root beads have been deposited. Fig. 10*A* is a cross-section macro specimen of a completed weld showing the contour of the root beads and the stringer bead technique used in the submerged arc weld; Fig. 10*B* shows two side-bend specimens.

Figure 11 shows several reduced section tensile specimens, all of which broke at a tensile strength above the minimum range of the chrome-molybdenum base material. Figure 12 is a photograph of a finished weld showing the smooth submerged-arc welding beads, as well as the uniform condition of the inside surface of the weld.

Figure 13 is a radiograph of the completed weld, which illustrates that radiographically sound weld deposits with good root bead conditions can be produced by this welding technique.

Conclusions

The following conclusions may be drawn as to the application of this technique in the fabrication of pressure piping systems:

1. The method of preparing the root edges of the joint definitely assures more desirable root bead conditions in all positions.
2. This technique does not require any special manipulation when applying the inert-gas-shielded arc weld; therefore, a welder can be trained to produce satisfactory welds in a very short period of time.
3. The method of burning up the paper dams with an oxy-acetylene flame, as illustrated in Fig. 4, is an innovation that is desirable and effective.
4. Although sufficient cost figures have not been accumulated as yet, there is every indication that the costs will be lower and the quality superior to those of other techniques.

Acknowledgment

The author wishes to express his gratitude to Stone & Webster Engineering Corp. for the permission to present this article, and to J. J. Cavanagh of the Stone & Webster Metallurgical Laboratory, who made the tests and took the photographs used in this paper.

By DONALD B. HOWARD

When considering the replacement of conventional electrodes with iron-powder electrodes, the user should make a careful analysis of his own specific end use and design

EVALUATING THE IRON-POWDER COATED ELECTRODES FOR PRODUCTION USE

Depositing test welds with iron-powder coated electrodes

Introduction

Weldment fabricators have been faced with the problem of whether or not they should use the American made iron-powder coated electrodes since their heralded introduction late in 1953. ACF Industries, Inc., recognized the problem and met it with a thorough evaluation which has been both realistic and technically sound.

Many production people were anxious to adopt the faster electrodes without a complete appraisal even though the electrodes were not classified under any code or specification at the time. Most attractive and desirable claims were initially advanced and many electrode users did not take the time to carefully check them against their own particular production applications.

A Dutch manufactured, iron-powder-coated electrode had been given close scrutiny in late 1948 and early 1949 in our laboratory. Insufficient penetration and unacceptable ductility levels were observed, and the electrode was not recommended for any production application.

Donald B. Howard is Supervisor, Metallurgy and Welding, Research and Development Department, American Car & Foundry Division, ACF Industries, Inc., Berwick, Pa.

Presented at the 1955 AWS National Spring Meeting, Kansas City, Mo., June 7–10.

It was believed that the iron-powder-coated electrodes should be tested as nearly as possible in accordance with the specification which governed the conventional electrodes which they were intended to replace. Our laboratory is quite well equipped and its staff includes an outstanding welder for manual operations, an operator for automatic welding, a burner and a fixture man. These men, all formerly contractually covered hourly workers, are now gainfully employed at a salary commensurate with their former earnings, and attack such a problem most objectively.

The new electrodes were marketed to be used in place of conventional electrodes. Two types were originally introduced. The rutile (titania) type iron-powder-coated electrode, now known as E6024 under the revised specification, ASTM Designation A233–55T or AWS Specification A5.1–55T (hereinafter called 55T), was designed to replace the E6012 electrode. The iron-oxide-type iron-powder-coated electrode, now known as E6027, was intended to replace the E6020 electrode.

The claims made for these then uncoded but excitingly named electrodes were as follows:

1. Anyone can weld.

2. High speed
3. Smoother welds
4. Easy slag removal
5. Crack resistant
6. No undercut
7. Good elongation

Eighty-five percent of our production welding was estimated to be horizontal fillets. Therefore, a search was made for an iron-powder-coated electrode suitable for this application without restrictions in general production welding.

An electrode is an operating supply and an investment which must benefit both the fabricator and the final user of the weldment which is being prepared. Acceptability of any electrode depends upon its specific application judged from an engineering point of view such as whether the weldment is subjected to static or dynamic loading.

Preliminary tests were performed on 23 different brands of electrodes this past year, Table 1. Five did not meet the preliminary test requirements and therefore were not given a complete evaluation. These were rutile-type iron-powder-coated electrodes. The other 18 were then completely evaluated in accordance with the requirements of ASTM Designation A233–48T also known as AWS Specification A5.1–48T (hereinafter called 48T), the tentative specification for Mild Steel Arc-Welding Electrodes as well as the 55T Specification.

Preliminary Tests

The so-called "luncheon" test was designed to screen the many electrodes being offered by vendors who were usually a half-day's drive from Berwick, Pa., the site of the laboratory.

A fresh box of $^{3}/_{16}$ x 18-in. iron-powder-coated electrode from a production lot would be furnished of either the rutile or iron-oxide iron-powder-coated type. This size was chosen in place of the $^{1}/_{4}$-in. conventional electrode commonly used for $^{1}/_{4}$-in. horizontal fillets.

The vendor was asked to specify:

1. Current, a c or d c
2. Amperage
3. Operating technique (drag or hold an arc) and angle of electrode to work

Several $^{3}/_{8}$-in. plates conforming to ASTM Designation: A285–52aT, Firebox quality, Grade C, were tacked together in preparation for the deposition of horizontal fillets. The current recommended was usually ac. The amperage range recommended generally exceeded a spread of 75 amp. Contact or "drag" technique was invariably suggested, and the electrode was most often held at an angle of 15 deg in the direction of welding. A series of $^{1}/_{4}$-in. horizontal fillets was prepared in 15/20 amp increments across the range suggested.

The first and last inch (start and crater) of the horizontal fillet weld were not considered in the evaluation. All welds generally had a very good surface appearance. Slag removal was usually easy, especially on the E6024 electrode weldments. Slag removal for some E6027 electrodes was more difficult. Some beads rolled a little and still others would not wash up sufficiently on the vertical leg of the horizontal fillet; both legs of a fillet weld should be of equal length within $^{1}/_{16}$ in.

Table 1—Manual Electrode Evaluation Effort (12-Month Period)

Electrode classification	*Preliminary test*	*Complete evaluation*	*Approval*	
			Limited	*Unrestricted*
E6012	5	5	1	3
E6020	4	4	2	1
E6024	10	5	4	0
E6027	4	4	2	1
Totals	23	18	9	5

All of the initial welds were fractured by subjecting them to the pressure of a 20-ton hydraulic jack. This practice of fracturing is not new, but much copied as it reduces the frequency of pulling the plate with the weld deposit, commonly experienced when welded

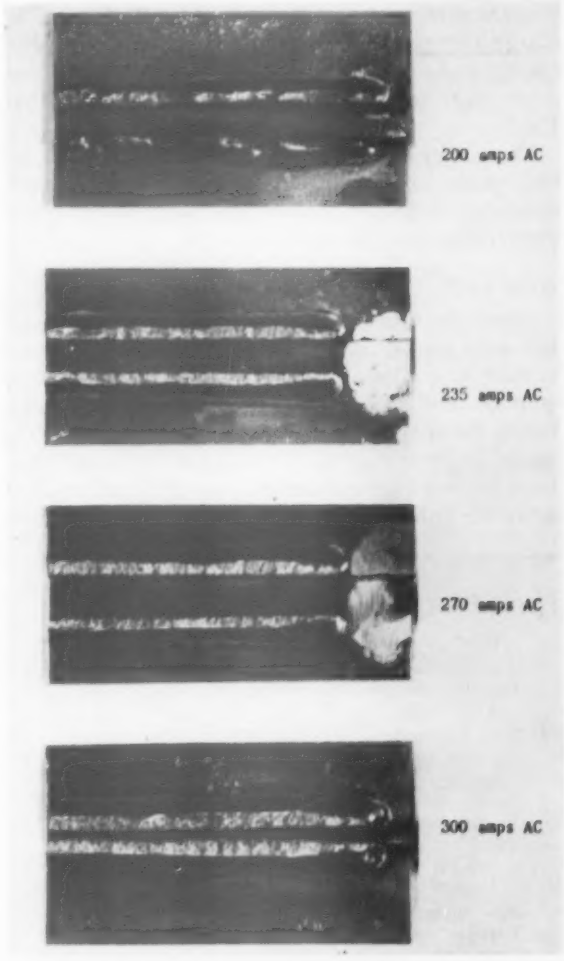


Fig. 1 E6024 electrodes—fracture of positioned $^{1}/_{4}$-in. fillets made with $^{3}/_{16}$ electrodes

Table 2—Typical Alternating Current Operating Ranges, Horizontal Fillets, 1/4-In. Conventional Electrode and 5/16-In. Iron-Powder-Coated Electrode

Electrode classification	*Amp*
E6012	285/345
E6020	285/345
E6024	275/305
E6027	250/280

joints are fractured by placing the weldment in a vise and battering it apart with a hammer.

These tests revealed that the acceptable operating amperage range for the iron-powder-coated electrodes was only one-half as great as that practiced with the conventional electrodes when fabricating horizontal fillets, Table 2, and much less than recommended.

The standard devised for acceptability depended upon adequate penetration and acceptable porosity. Adequate penetration meant that each fillet weld had penetrated to or beyond the root of the joint for its entire length. Acceptable porosity meant that the total number of holes or voids did not exceed one per inch of fracture under examination. Without exception, all iron-powder-coated electrodes checked in this fast manner had a relatively narrow amperage range where penetration was adequate and porosity was acceptable, Fig. 1.

Three more horizontal fillets were then prepared, one each at the top, middle and bottom of the acceptable amperage range, for radiographic examination before proceeding to the complete evaluation.

Acid Test

Electrodes which successfully passed the preliminary test were usually given a more thorough review and evaluation costing over $650 patterned after the requirements of 48T. Most of the work was completed before the final acceptance of Specification 55T. The variations introduced in this new tentative specification were thoroughly investigated, however, and we cooperated with Working Group A, Arc-Welding Electrodes, Subcommittee 1, Iron and Steel Filler Metal, AWS-ASTM Committee on Filler Metal during its formulation, even though our concepts were in the minority in several instances.

Several conventional E6012 and E6020 electrodes were also checked in accordance with the 48T specification in order that a realistic base for comparison might be established. It was learned during this portion of the over-all study that not all conventional electrodes conform to the specification across the board. Such discrepancies were called to the attention of the vendor who in some instances would send his test welder to our laboratory to make weldments as required by the specification alongside our welder.

The electrode user should know that, by and large, the only police force assuring consistently high electrode quality is the manufacturer. There is no control body to accomplish this important work. Several reputable vendors acknowledge that they check completely each type of electrode they produce against the governing specification but once a year. Certainly the user should make more frequent checks himself to be assured of quality fabrication made with consistently good electrodes.

The final evaluation included the following:

1. All-weld-metal tension test
2. Guided-bend test
3. Macro and microexamination
4. Impact resistance tests
5. Operating characteristics

All-Weld-Metal Tension Test

This test proved to be the key to an objective evaluation for all electrodes tested. It compares the yield strength, tensile strength and elongation levels of weld metal of competitive electrodes.

Results varied depending on techniques employed. The preparation of the specimen differed when the new 55T specification was followed. This tentative specification was urgently needed and is the result of much effort and work of many people. The yield, tensile and ductility requirements for the iron-powder-coated elec-

Table 3—Mechanical Properties

	Electrode classification	*No. samples*	*No. brands*	*Yield point, psi*	*Tensile strength, psi*	*Elongation, % in 2 in.*
Spec. minimum	E6012			55,000	67,000	17
Expected range				55/65,000	68/78,000	17/22
Avg		26	5	62,700	72,900	18.5
Spec. minimum	E6020			50,000	62,000	25
Expected range				52/58,000	62/68,000	25/30
Avg		22	4	56,900	65,200	22.5
Spec. minimum	E6024			55,000	67,000	17
Expected range				65/75,000	77/87,000	17/22
Tests		65	5			
Avg per 48T				81,000	88,200	10.8
Avg per 55T				75,000	81,700	24.3
Spec. minimum	E6027			50,000	62,000	25
Expected range				52/58,000	62/68,000	25/30
Tests		46	4			
Avg per 48T				63,200	70,500	19.4
Avg per 55T				59,400	67,800	27.8

trodes were established at the same levels as their conventional counterparts. The elongation value could only be achieved, however, by incorporating two important technique changes to be used in the preparation of the all-weld-metal tension test specimen; namely (1) the use of the interlayer rather than interpass temperature control and (2) the incorporation of artificially aging the machined specimen at 200 to 220° F for 24 to 48 hr before subjecting it to the tension test.

Average mechanical properties, Table 3, indicated that the minimum yield and tensile requirements for the conventional E6012 and its E6024 iron-powder-coated counterpart were easily met. The expected yield and tensile range for E6024, however, is not realistic in the new specification, because its low side is still 10,000 psi above the minimum specified yield and tensile. The average value for 0.505-in. specimens tested in this class in accordance with 48T had exceeded even this range for both yield and tensile. When tested in accordance with 55T, the yield point was at the upper limit of the expected range and the tensile fell within the expected range.

The yield and tensile values for E6020 and E6027 electrodes were much more realistic with E6020 average values lying within the established range and E6027 values lying generally above the range, the low side of which expected range was only 2000 psi above the specified minimum for yield and coincided with the minimum tensile value.

Elongation, on the other hand, was quite a different story. Some of the conventional electrode brands tested did not meet the specified measure of ductility when tested in accordance with the 48T procedure. The 18.5% average of E6012 specimens tested was the only one which met the 17% minimum requirement, E6020 average values exceeded this elongation at 22.5% which is short of the 25% stated minimum of the specification. A few specimens prepared and tested to 55T did not show appreciably improved elongation for the brand in question. Our Engineering Department would approve a minimum ductility level as low as 15% elongation for certain specific applications.

The average elongation values for the iron-powder-coated electrodes evaluated depended upon the technique followed in preparing the specimen. When provisions of 48T were followed, average E6024 elongation values were 10.8%, but this average improved to 24.3% when 55T was followed using interlayer temperature control and artificial aging. A similar pattern was observed when determining average elongation for the E6027 class. When the 48T technique was adhered to, an average elongation value of 19.4% was achieved. Interlayer temperature control and artificial aging as specified in 55T raised this value to an average of 27.8% on samples tested. In both instances, yield and tensile were lowered as elongation improved, as could be expected. Other specimens, prepared to non-standard techniques such as using either interlayer temperature control or artificial aging, but not both, had elongation values of a higher order than attained following 48T.

Table 4—E6024 Rutile Type Iron-Powder-Coated Electrodes, Effect of Interlayer Temperature Control and/or Artificial Aging

Temperature control, 212° F	*Aging temperature, ° F*	*Specimen*	*Elongation, % in 2 in.* *Brand A*	*Brand B*
Interpass	75	1	12.0	13.0
Interpass	75	2	14.0	14.0
Interpass	210*	1	19.5	25.0
Interpass	210*	2	21.0	21.5
Interlayer	75	3	17.5	17.0
Interlayer	75	4	17.0	17.0
Interlayer	210*	3	29.0	26.5
Interlayer	210*	4	29.0	26.5

Minimum elongation requirements per ASTM A233-55T, 17%.

* Artificial aging duration was 36 hr. All specimens tested on seventh day after being welded.

Two competitive electrodes supported this observation dramatically, Table 4. It was observed that:

1. The two competitive electrodes were consistent.
2. Interlayer rather than interpass temperature control raised elongations about 30%.
3. Artificial aging raised elongations even more.

The obvious differences between the test methods resulted in widespread variation in ductility levels as expressed by elongation. Since most conventional electrodes examined met the elongation level in the manner defined in the 48T specification, these booster techniques became most pertinent and controversial, especially when elongation values of substandard specimens prepared from single-pass horizontal fillets were comparable with 0.505-in. specimens prepared to the 48T specification technique.

One salient contributory factor to the unaged iron-powder-coated electrodes was the type of fracture of the all-weld-metal tension test, Fig. 2. Most broke in an

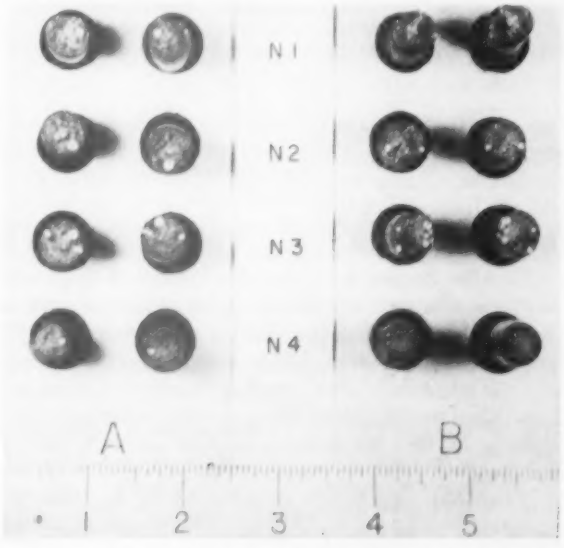


Fig. 2 E6027 electrodes—fracture of all-weld tensile specimens

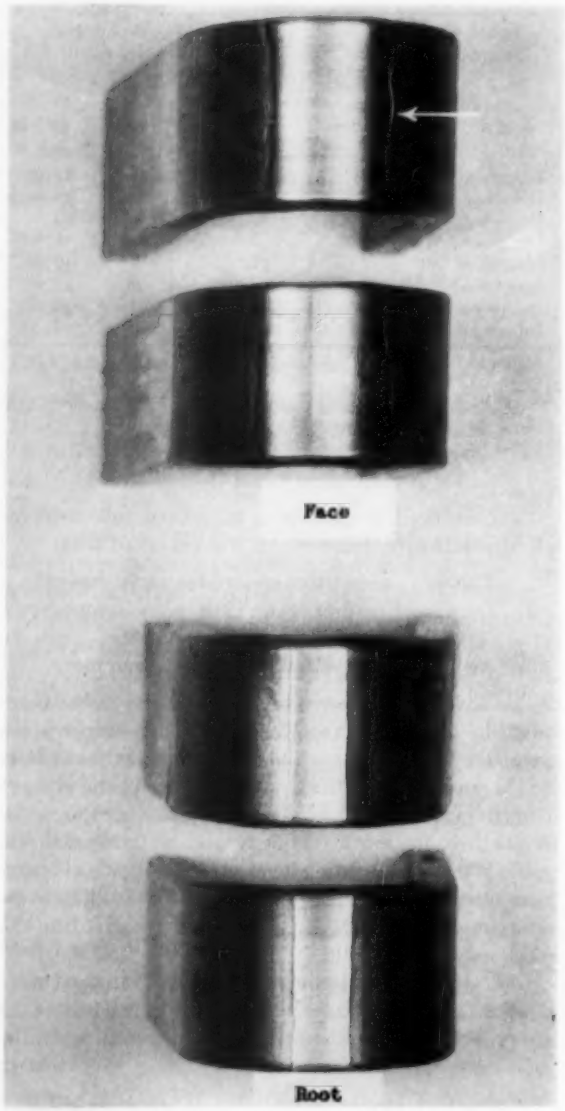


Fig. 3 E6024 electrodes—root and face guided U bends

irregular brittle manner and the fracture face invariably contained "fisheyes" which are usually associated with hydrogen. Aging reduced this condition and a more ductile fracture resulted.

Guided-Bend Test

This test proved to be the least critical of those used in the evaluation. Certainly its importance cannot be underestimated when considering weld soundness for production fabrication. Both the old and new specifications state that, after bending, the guided-bend test specimens shall have no crack or other open defect exceeding $^1/_8$ in. No mention is made as to frequency, however.

Face and root bends were tested in duplicate for each class of electrode, Fig. 3. This figure shows the only failure encountered, but several specimens had more than one discontinuity, each being less than $^1/_8$ in.

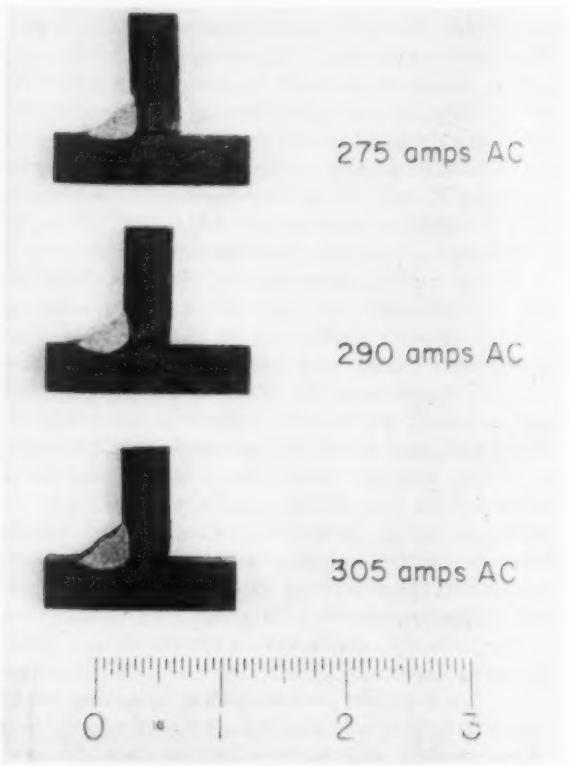


Fig. 4 E6024 electrodes—macrosections of $^1/_4$-in. horizontal fillet welds

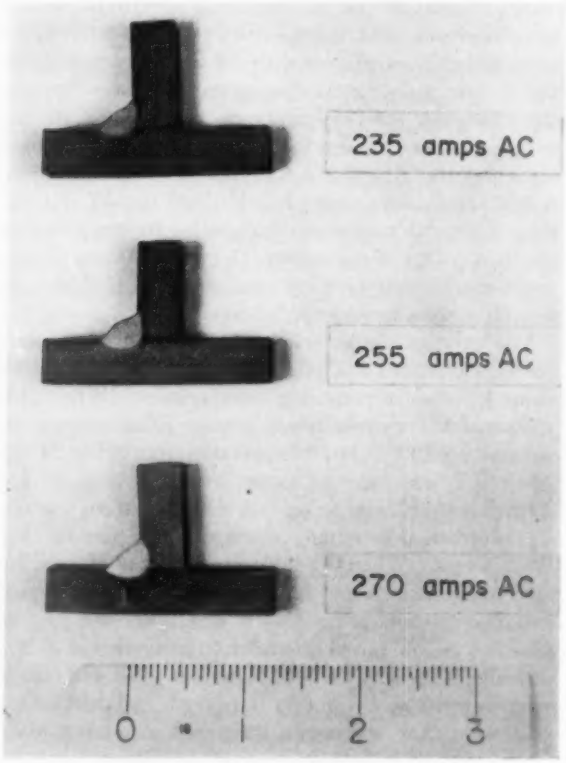


Fig. 5 E6027 electrodes—macrosections of $^1/_4$-in. horizontal fillet welds

Fig. 6 E6024 electrodes—macrosection of multipass weld

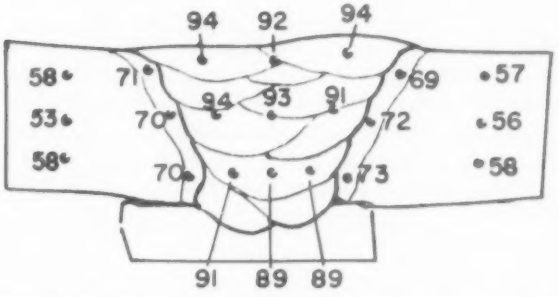


Fig. 7 E6024 electrodes—hardness survey across weldment

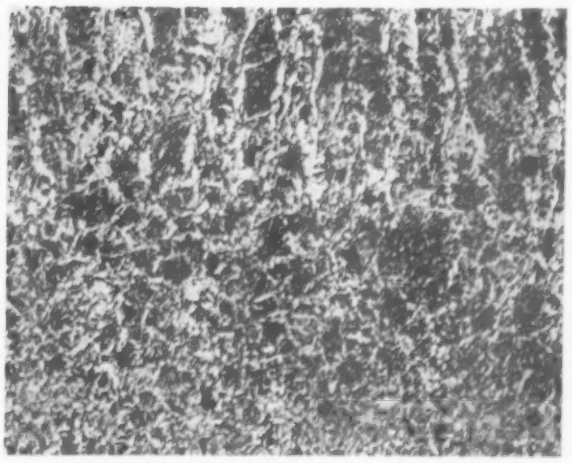


Fig. 8 E6024 electrodes—microstructure of weld deposit at junction of two passes

long. Specimens were machined from the same test plate with face- and root-bend specimen positions alternating along the welded plate.

Side bends required a different joint preparation and again the test was conducted in duplicate.

Table 5—Impact Resistance, Ft-Lb, Charpy Keyhole

Electrode classification	*Temperature, ° F.* +70	−40	−70	−100
E6012				
Spec. guide	20/30	15/20	...	...
Tests	21/30	4/23	...	2/20
E6020				
Spec. guide	20/30	15/20	...	...
Tests	23/28	16/24	...	14/23
E6024				
Spec. guide	20/35	15/20	...	...
Tests	18/33	13/24	3/25	3/15
E6027				
Spec. guide	25/35	20/30	...	...
Tests	26/36	22/28	15/26	...

Macro- and Microexamination

The integrity of the macro and microexamination depended to a large degree upon the quality of workmanship that went into both its preparation and that of the weldment, Figs. 4 and 5.

Macro studies revealed the degree of penetration, soundness and the extent of the refining effect of subsequent passes on previous deposits, Fig. 6. All but the final pass showed this annealing condition. This observation was confirmed by Rockwell "B" hardness surveys, Fig. 7, made from base metal, through the heat-affected zone to the weld itself, including both root, intermediate, and top or cover passes.

The microexamination was made on both unetched and etched specimens. Results showed that an acceptable and normal frequency of nonmetallic oxide type inclusions was present and that the final cover pass of the multipass weld was of a coarse dendritic structure. The partial annealing of intermediate passes was again observed, Fig. 8.

Impact Resistance Tests

Impact resistance properties were given in Izod ratings in the 48T specification. The new 55T specification adopts the Charpy keyhole method as a standard. Much attention has been given this feature by the vendors with values for several temperatures established. The values appear in the appendix of the specification at 70° F and −40° F and are not mandatory but furnished as expected values.

As much of our work was done at −70° F as was done at −40° F. This was necessary to observe the lower transition temperature levels characteristic for these electrodes, Table 5. About one hundred and fifty specimens were machined for this portion of the effort. Additional tests were made using the Charpy V-notch type test specimen which reveals a more sensitive but higher transition level.

Operating Characteristics

Welding data were obtained for each electrode fully evaluated. Tests were made in triplicate at the top, middle and bottom of the acceptable workable amperage range for both the E6024 and E6027 iron-powder-coated electrodes as well as their conventional counterparts, E6012 and E6020, respectively.

This work included:

1. Burn-off rate, ipm
2. Speed, ipm
3. Deposition rate, lb per hr
4. Efficiency, %

All welding was accomplished by preparing 1/4-in. horizontal fillets using 5/16-in. iron-powder-coated electrodes and 1/4-in. conventional electrodes.

For purposes of comparison, the maximum values, which always occurred at the highest allowable amperage setting, were used, Table 6. The minimum values listed are the lowest obtained for any individual electrode examined at its highest acceptable amperage setting.

Burn-off rate reflects the consumption of flux-coated electrodes during welding and is measured in inches per minute. This work indicated that the E6024 electrode had a 30% greater burn-off rate than the E6012. E6020 and E6027 electrodes had similar burn-off rates.

Speed indicates the actual length of weld metal bead deposited and is, perhaps, the most valuable data obtained during such a closely controlled test when considered from a production point of view. The human element may be conspicuous here, but consistent results can be expected when the same first-class manual welder performs all the tests. These tests revealed that the fastest E6024 electrode was 36% faster than its fastest E6012 conventional counterpart. The E6027 iron-powder-coated electrode, however, was but 21.5% faster than the fastest conventional E6020 electrode evaluated. The smaller speed advantage of the E6027 electrode, even though faster than E6012 and E6024, limits the use of this premium electrode as a replacement for the E6020 class electrode.

Maximum deposition rates were within 1.5 pounds an hour for all four classes of electrodes tested. E6024 electrodes had the most uniform deposition rates. The differences in speed were not proportionately reflected in the deposition rates, however.

Efficiency is the ratio of weld metal deposited to electrode consumed. Volatile losses and spatter were revealed by this appraisal. Over one hundred and seventy tests showed that the E6012 electrodes had the consistently greatest efficiency at the maximum operating amperage allowable. The other three classes performed closely alike at a lower efficiency.

Observations

Deficiencies were found in several of the 18 electrodes evaluated which caused much concern since the electrodes used in the laboratory tests were fresh boxes produced as a part of a production lot.

The newly revised specification is an expedient in answer to the urgent demand to cover and classify in some orderly manner the recently introduced American made iron-powder-coated electrodes. It was found that the modifications incorporated in the new specification, namely, interlayer rather than interpass temperature control and artificial aging of all-weld-metal tension specimens, do result in a higher ductility level for the iron-powder-coated electrodes than would be possible if the 48T version of the specification were followed.

Some investigators have found that the all-weld-metal tension and guided-bend test iron-powder-coated electrode specimens must be prepared using stringer passes deposited with the "drag" or close arc technique since weaving results in slag entrapment.

Results obtained by carefully controlled laboratory tests are only as important and worthwhile as their evaluation and subsequent production application. One can easily improve elongation, the measure of ductility, on a laboratory scale, by using one or a combination of two or more of the following techniques which might result in elongations which we have found to be higher than those obtained when testing specimens machined from single-pass fillets:

1. Interlayer rather than interpass temperature control.
2. Artificial rather than no more than one week's room temperature aging.
3. Holding a short arc rather than using the "drag" or contact technique.
4. Welding uphill on a 5-deg slope.
5. Reduce amperage below levels required for adequate joint penetration.
6. Removing specimen from test plate for machining by flame cutting rather than by mechanical means.

The iron-powder-coated electrode is here to stay. Rapid improvement has been noted in the performance of electrodes produced by some manufacturers when compared to those initially offered for testing just over a year ago. The user must be willing to get the facts himself by analyzing his peculiar and particular end use and design. There are desirable features in each of the iron-powder-coated electrodes which have been observed in our laboratory. It is hoped that these plus factors can all be incorporated into one electrode in the near future.

Table 6—Welding Data

	Burn-off rate, ipm		*Speed, ipm*		*Deposition rate, lb per hr*		*Efficiency, %*	
Classification	*Min*	*Max*	*Min*	*Max*	*Min*	*Max*	*Min*	*Max*
E6012	9.0	10.3	7.7	10.2	6.6	8.4	63	84
E6020	9.8	12.3	9.7	12.5	7.7	9.5	65	75
E6024	12.0	14.2	10.8	13.9	8.4	9.4	64	72
E6027	10.2	13.0	10.6	15.2	7.5	9.9	64	71

SOME NEW CONCEPTS ON WELDING QUALIFICATION REQUIREMENTS

BY S. A. GREENBERG

Qualification in welding is a subject of discussion in the welding industry very much like the weather in social circles—everyone has his own ideas about it and what should be done about it. However, unlike the weather we must *do* something about qualification. This is the very difficult problem of the AWS Committee on Standard Qualification Procedures. This Committee has been giving serious consideration to some of the principles on which present-day qualification requirements are based. This was the subject of the Symposium on Qualification sponsored by the Technical Activities Committee at the Annual Spring Meeting of the Society in Kansas City this past June.

Briefly, the new concept provides that the degree of qualification required for a joint welding procedure be based on the severity of service conditions for which a product or structure is designed. Thus, 15 different service classifications have tentatively been established as follows:

S1. Welds which are not significantly stressed in service nor are required to provide required gas tightness. Such welds are intended primarily to hold component parts together.
(Typical applications would be: enclosure, shields and boxes)

S2. Welds required to provide thermal, electrical or magnetic conductivity without any significant stress imposed on the weld.
(Typical applications would be splices in electrical conductors; studs or plates attached to a surface to provide an extended surface for heat exchanging; welded joints in transformers intended to provide continuity of magnetic circuit.)

S3. Welds required to provide liquid and gas-tight joints at atmospheric pressures without being subjected to significant stress in service.
(Typical applications would be welds in drain pipes and air ducts.)

S4. Welds required to carry static loads at room temperature.
(Typical application would be expanded light gage structural frames used in building construction.)

S5. Welds required to provide liquid and gas tightness at room temperature under pressure.
(Typical applications would be pressurized gas container; and hydraulic accumulators.)

S6. Welds required to operate under dynamic loading and at room temperature.
(Typical application would be supporting members on truck bodies.)

S7. Welds required to carry static loads at elevated temperature.
(Typical application would be structural supports in furnaces.)

S8. Welds required to operate under dynamic loads at elevated temperatures.
(Typical application would be a conveyor in a furnace.)

S9. Welds required to provide liquid and gas-tight joints at elevated temperatures and under pressure.
(Typical applications would be an unfired pressure vessel; locomotive boiler.)

S10. Welds required to operate under static loads at low temperatures.
(Typical application would be an outdoor transmission tower.)

S11. Welds required to operate under dynamic loads at low temperatures.
(Typical application would be highway bridge in the northern parts of the United States.)

S12. Welds required to provide liquid and gas-tight joints at low temperatures and under pressure.
(Typical applications would be liquid oxygen storage tank; outdoor water storage tank.)

S13. Welds required to operate under high velocity impact loads at room temperature.
(Typical application would be a pile driver.)

S14. Welds required to operate under high velocity impact loads at low temperatures.
(Typical application would be armored plate on a tank.)

S15. Welds exposed to corrosive environments. Any weldment of classifications S1 to S14 which is subject to the action of a corrosive medium.

S. A. Greenberg is Technical Secretary of the American Welding Society.

Summary of presentation at Symposium on Qualification held at 1955 National Spring Meeting, Kansas City, Mo., June 7–10.

In those cases where corrosion may adversely affect the performance of the weldment in service, additional tests would be conducted to assure that the welded joint will satisfactorily withstand the corrosive environment. The nature of such corrosion test would be a matter of agreement between the manufacturer and the purchaser.
(Typical application would be an acid storage tank.)

As a measure of the suitability of any given joint welding procedure for producing welded joints to satisfy any one of these classifications of service requirements a series of tests have been proposed as follows:

T1—Visual Examination
T2—Macroetched Section
T3—Tension-Shear Test
T4—Tension Test
T5—Hardness Test
T6—Impact Test
T7—Radiographic Examination
T8—Pillow Test
T9—Fatigue Test
T10—Bend Test
T11—Hydrostatic Test
T12—Twist Test
T13—Peel Test

As can be seen from this list of tests, use will be made of established tests in so far as possible. New tests may have to be formulated and standardized to evaluate other service conditions not covered by existing tests.

Another purpose of the Symposium was to stress a point too often overlooked in industry. Roger Clark, General Electric Co., as first speaker, pointed out the necessity of giving proper consideration to all factors involved in the application of welding. It is not enough to qualify your joint welding procedures and your welders. Proper attention must also be given to an evaluation of the service conditions and these must be considered in making a suitable design and in the selection of base metals and filler metals. Also due consideration must be given to the necessity for preweld and postweld heat treatments. For the sake of efficiency and economy the welding operations must be planned and suitable welding sequences worked out. For the same reason suitable equipment, properly maintained, must be used. To obtain proper workmanship and to see that the design requirements are followed in the shop there should be adequate supervision and training of personnel and quality control measures used. Finally, there must be an inspection of the finished product.

The importance of proper consideration of all these factors, not just qualification alone or in combination with only one or two of the other factors, was stressed again and again in the course of the symposium. With full consideration of all the factors to the extent necessary for any given product, and by application of the new concept of having the extent of qualification of a joint welding procedure related to the severity of service conditions, it is intended that code requirements will reflect the true position of qualification. The extent of qualification testing will be no greater than necessary. Thus it may be that a workmanship sample alone will be adequate qualification for service condition S1 or perhaps for a high service classification where more extensive quality control measures are used.

Present day qualification requirements are provided essentially for steel to be joined by either gas welding or some of the arc welding processes. Other requirements have been written for some of the nonferrous metals and for some other processes; these have been modifications of the older requirements rather than a basic evaluation of the metal or process involved.

The "new approach" introduced at the Symposium is to be used to establish requirements for all welding processes and all metals commonly welded today. Gus Hoglund, Aluminum Company of America, described, how a joint welding procedure for arc welding aluminum would be qualified on the new basis. Jim MacKinney, of the Budd Co., discussed the new qualification requirements for the resistance welding processes and Art Kugler, Air Reduction Sales Co., described the qualification of procedures for all of the eight brazing processes. Si Greenberg, AMERICAN WELDING SOCIETY, showed how it will be possible, using the new approach, to more readily establish requirements for new processes and metals as they appear in the future. In conclusion, he again emphasized the need for considering all of the factors in producing a weldment, not just qualification alone. Moreover, he pointed out how useful qualification of a joint welding procedure is in establishing a working joint welding procedure before putting it into use on production. This is true whether or not qualification is required to meet a code. It is equally true for ash cans, or toys or the most highly stressed structure.

Qualification of welders and welding operators also is to be related to the service classification and degree of quality control, as well as the welding process used.

As could be expected, the discussion which followed the formal presentation was long, and at times heated. Comments on the proposals presented could be summarized as follows: It was agreed that the Committee on Standard Qualification Procedures was on the right track. In fact, when asked for an indication of approval or disapproval of the approach, the 250 men in the audience all raised their hands in approval, with one man dissenting. On the one hand, it was suggested that the actual testing specified be simplified, even to the extent of requiring only one test for any given procedure. On the other hand, another suggestion was made that the testing be sufficiently extensive to comprehensively evaluate the required properties of the welded joint.

Recognizing the difficulty of trying to fully analyze the new concepts from an oral presentation alone, and because the Committee would like to have the reactions of as many people from industry as possible, this brief summary is being published. Your comments, suggestions or criticisms are needed to help reflect your needs in the final formulation of new qualification standards. They will be most welcome. Address all commmunications to Secretary, Committee on Standard Qualification Procedures, AMERICAN WELDING SOCIETY, 33 W. 39th St., New York 18, N. Y.

SCIAKY OPENS WESTERN RESEARCH DIVISION

Sciaky Bros., Inc., recently held open house at their Western Research Division, 2311 Purdue Ave., West Los Angeles. Sciaky, one of the leading manufacturers of electric resistance welders in the world, has plants in Chicago, London, Paris.

The Research Division specializes entirely in resistance welding and its related problems. The modern 15,000 sq ft building, powered by a 3000-kva high voltage bank transformer, was designed especially for research purposes. Provision was made for special laboratories, testing machines, metal preparation, machine shop and a complete line of welding machines including the world's largest spot welder and seam welder.

Research Staff

The research staff of scientists, engineers and technicians is under the leadership of Mario Sciaky, one of the four brothers heading the company. Location of the research center on the West Coast was considered necessary due to the immense amount of research and development being undertaken by the aircraft and electronic industries in this area.

Program of Activity

A broad and thorough program has been laid out by the Research Division. In general two plans are being followed: First, specific problems or investigations desired by users or potential users of the resistance welding process. These problems are presented to the Sciaky research team for their investigation.

A second plan being followed is for basic research into the resistance welding process. This involves the study of resistance welding and its behavior with various metals, variations in conditions such as those imposed by ultra-sonic speed and thermal conditions, low and high pressures, fatigue, tension and impact stresses.

Fig. 1 Partial view of welder line at the Sciaky Research Division

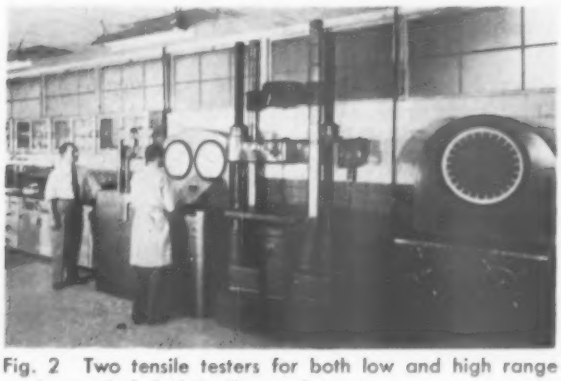


Fig. 2 Two tensile testers for both low and high range work are included in the equipment

Fig. 3 This huge welder, the largest spot welder in the world, is capable of delivering 300,000 amp of welding current and 38,000 lb pressure

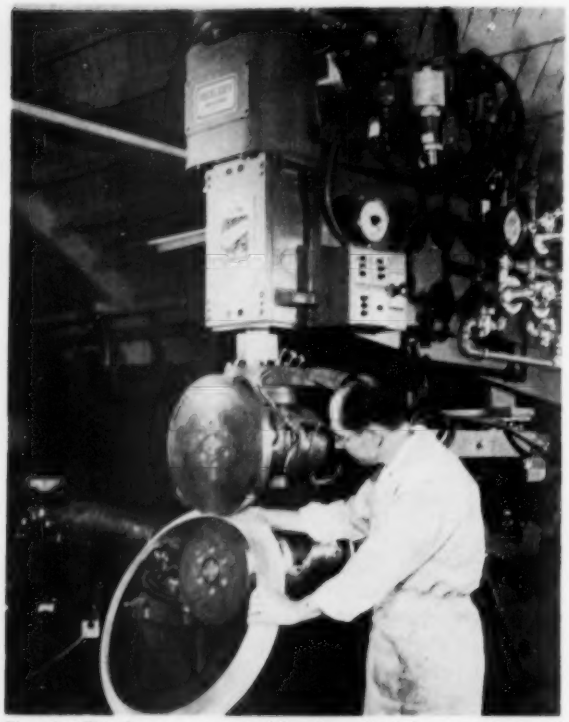


Fig. 4 This large seam welder has dual lower arms and universal upper head to provide quick changeover for either transversal or longitudinal welding

The development of adequate instrumentation for resistance welding research, service, monitoring and inspection.

Source of Technical Data

Other phases of the research program involve the developing of technical information such as application, joint patterns, structural qualities, economics of resistance welding design, and the making of this data known and available to industry. A specialized technical library for industry is being developed.

According to spokesmen for the company, Sciaky is offering its entire research facilities to industry by conducting special research programs, the design and development of welded products, prototype development, limited production and pilot runs, the development of special tooling, electrodes and machines.

Complete Resistance Welding Facilities

The facilities available at the Western Research Division include several types of spot and projection welders, seam welders and flash butt welders (see Figs 1-4).

All available machines are capable of welding various materials such as aluminum alloys, stainless steels, mild and zinc-coated steels, alloys of brass, chrome molybdenum alloys, nickel, Inconel, Nimonics and other high heat-resistant materials, titanium, etc.

Laboratory Facilities

The laboratory equipment at the research center consists of the following: Metallograph, tensile testing machines up to 120,000 lb force, hardness and surface indicators, cathode-ray oscillographs, electronic indicators, photographic and darkroom equipment, chemical and metallurgical analyzing equipment, ultrasonic, X-ray, fatigue and impact testing machines.

Also included are a complete machine shop, stock of materials and metal cleaning and preparation facilities.

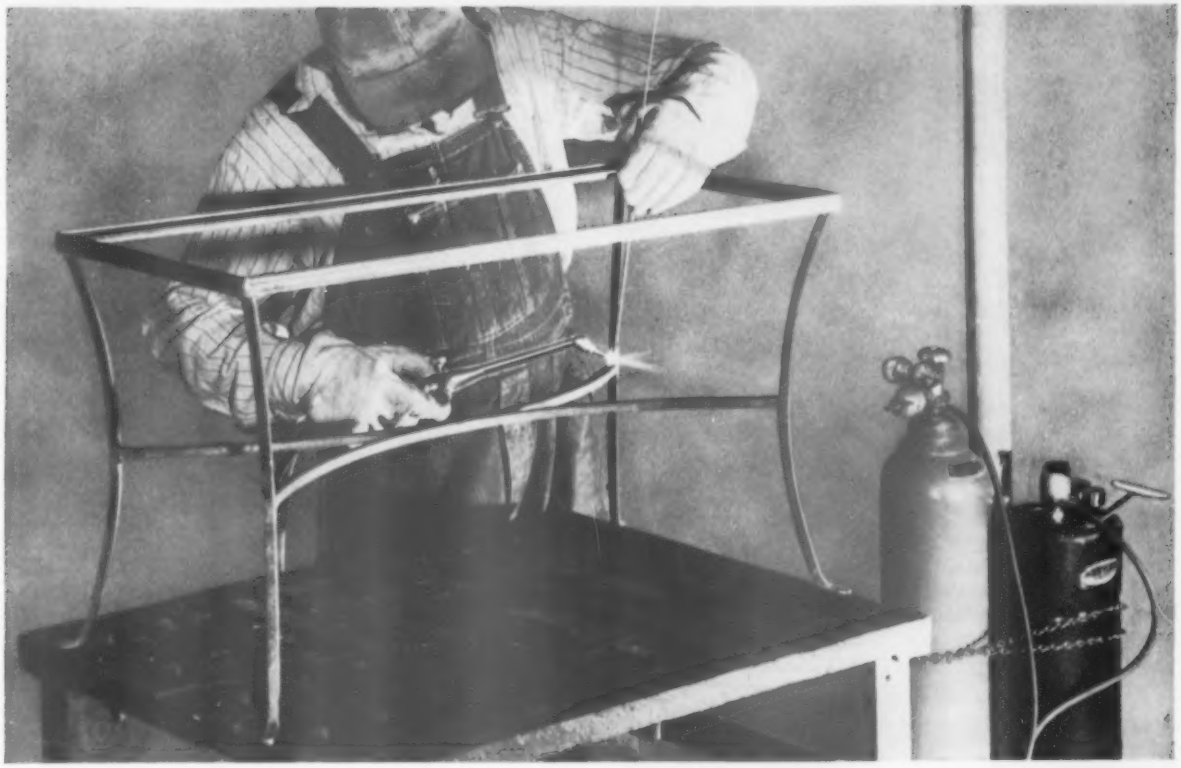
SPECIAL PACKAGE OFFER— AWS CODES AND STANDARDS

The Society has made available a "package" arrangement whereby any individual, library or company may purchase a complete set of codes, standards, specifications and books on welding published by the Society and covering the subjects of Fundamentals of Welding; Training, Inspection and Control; Processes; and Industrial Applications. Complete set of these publications are listed under general classifications A, B, C and D of the 1955 Order Form which will be furnished upon request. In addition to these existing publications, two binders are supplied for containing same and *a 10-year service is provided whereby the subscriber automatically receives new or revised standards issued during the next 10 years.*

This complete "package" of present publications, binders and 10-year service is available to companies who support the Society through Supporting Company membership at a price of $25; members enrolled in the Member (B) Grade classification as well as libraries (public, school or other endowed) at a price of $35; members enrolled in the Associate Member (C) Grade classification at a price of $39 and to nonmembers of the Society at a price of $50.

In the instance where the 10-year service alone is desired (no binders or existing standards furnished), the price to Supporting Companies is $10; "B" members and libraries $17; "C" member $19 and nonmembers $27.

Your order should be accompanied by either check, money order or company purchase order and mailed to American Welding Society, 33 W. 39th St., New York 18, N. Y.



POPULAR WROUGHT IRON FURNITURE IS EASILY MADE BY BRAZE WELDING

A welding torch and a few hours' time make this attractive luncheon set

BY A. J. BELDON

Decorative wrought iron furniture has become increasingly popular with today's value-conscious home owners. And there's a good reason for this sudden popularity. The graceful lines of wrought iron lamps, ash trays, coffee tables, outdoor dining sets, magazine racks and other pieces not only add beauty to any home decorating scheme; they also offer an unbeatable combination of low-cost style and usefulness.

Building useful furniture like this is a natural for the job shop. For example, an attractive four-place luncheon set can be made in a few hours from inexpensive mild steel stock. An oxy-acetylene torch-brazing flux and some bronze welding rod are all that is needed in the way of equipment to do the job. The intense heat of the oxy-acetylene flame makes an easy job of the heating, forming, welding and cutting work that quickly transforms a few pieces of steel stock into this decorative set for dining room or terrace.

Parts for the furniture are first measured, and then cut to size. You can check store models for measurements, or work out your own measurements to meet special requirements. After cutting, the various parts are heated with the oxy-acetylene flame and bent to shape. Simple braze welds are then used to join the

A. J. Beldon is associated with Linde Air Products Co., Birmingham, Ala.

Fig. 1 A braze-welded joint is made in a single piece of steel stock after heating and bending it with the oxy-acetylene flame. This piece will make the seat frame for one of the four chairs

Fig. 2 Two braze welds, one on each leg, join the chair seat frame to the rear legs. Before welding, all parts were measured and cut to size by oxygen cutting

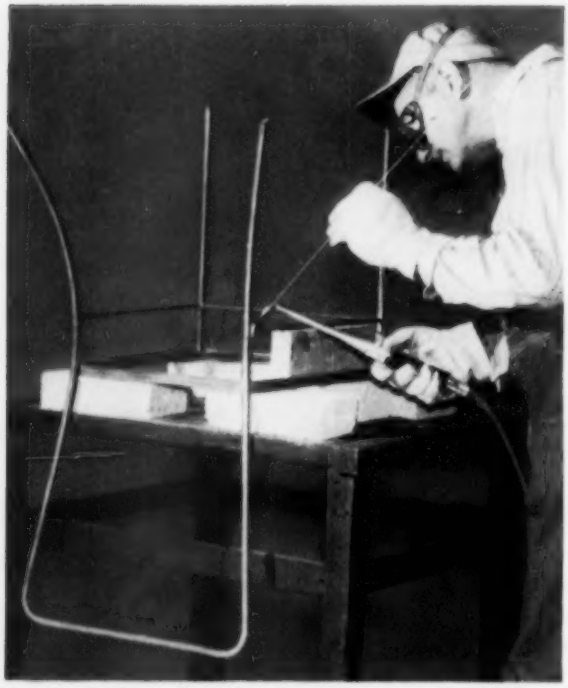


Fig. 3 Bricks and blocks of wood are used to support wrought-iron braces as they are braze welded to the legs. Parts should be thoroughly cleaned before welding to assure sound joints

Fig. 4 A decorative scrollwork like this one forms the back-rest for each chair. The scrollwork is made by heating and bending round bar stock with the flame of the oxy-acetylene torch

parts together. Braze welding is the easiest and fastest way to make the strong joints in this type of furniture that will assure a lifetime of sturdiness for each piece. Special finishing operations usually are not needed.

Building the set

Here's how to build this useful dining set.

1. Cutting

The first step is to cut the metal stock into exact size for the various parts. After determining the measurements for each part, use chalk, soapstone or a punch to mark the line of cut. Rest the blowpipe across the first knuckle of the left hand and place the outside edge of your left hand on a block about 10 in. from the line of cut. Use the left hand as a roller to give the blowpipe a steady, level movement. This will assure a smooth, straight cut every time.

2. Cleaning

Thorough cleaning of the parts to be welded is the secret of all good braze welds. Use a wire brush or steel wool to remove all oil, grease, rust or scale from each part at the point where the weld is to be made. If parts are not cleaned properly, the molten bronze rod will not flow smoothly over the weld area during tinning. This, in turn, will result in a weak joint.

3. Preheating and Tinning

With the parts supported in place, preheat the entire weld area by holding the inner cone or small white part of the flame about $^1/_4$ to $^1/_2$ in. from the metal. Do not melt the base metal. Just heat until it turns a dark red. Preheating enables the molten rod metal to bond solidly to the base metal and form a strong joint.

When the metal turns a dark red, you are ready to start tinning. Heat the end of the rod while preheating the weld area and dip it into the flux. Then touch the fluxed end of the rod to the preheated area under the flame. If the metal has been brought to the right temperature, and the weld area thoroughly cleaned, the molten bronze will flow evenly over the joint.

4. Braze Welding

After tinning, hold the rod against the base metal, and as a molten puddle forms, move the rod and flame slowly around the weld area adding metal from the rod at the same time. If you are using a standard bronze welding rod, dip it into the flux often while welding. This is important, because flux acts as a cleansing agent by removing impurities from the weld area, and thus assures clean, nonporous welds.

If the molten puddle gets too large or begins to run, pull the flame back for a few seconds to give the metal a chance to solidify. Welding is completed when the entire weld area is filled with hardened weld metal. Allow to cool slowly, away from drafts and then remove excess flux and metal with a wire brush and file.

Points to Remember

Braze welding is a quick and easy way to fabricate this type of furniture. But successful braze welds depend on not one, but a combination of 9 favorable conditions. These conditions can be obtained only by adhering to proper braze welding techniques. You will get clean, strong joints every time if you remember to follow these important steps:

1. Thoroughly clean the weld area.
2. Avoid melting the steel when preheating. Just heat to a dull red.
3. Move the flame and puddle slowly around the weld area. If the puddle bubbles the work is too hot—draw the flame back for a few seconds.
4. Dip the rod into the flux often.

Fig. 5 Here, the table top frame is welded into a closed rectangle. Preheat the entire weld area to a dull red. When welding, be sure to move the flame and molten puddle slowly around the weld area

Fig. 6 After you form the table top, braze weld the legs to the underside of the frame. Allow each weld to cool for a few moments before you remove the excess flux and metal with a wire brush

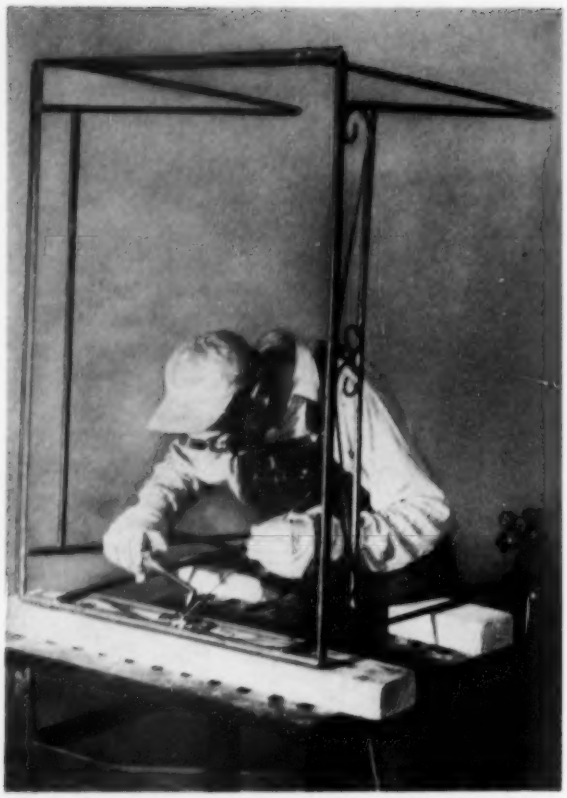


Fig. 7 Decorative scroll gives this piece the elegant lines that make wrought ironwork so popular with home owners. The scroll is easily formed by heating with torch

Finishing Touches

Decorative scroll can be used to put the finishing touches on each piece of furniture. Just heat round steel bar stock with the oxy-acetylene flame and bend into shape. A coat of paint, chair cushions and a glass table top complete the set—a truly functional addition to the home that will always be in style.

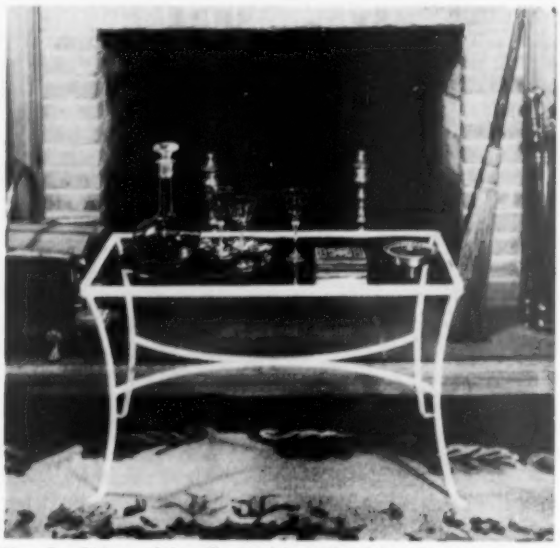


Fig. 8 This useful coffee table will add style to any room of the house. Parts for the table were cut from $^1/_2$-in. square mild steel stock with a cutting torch

TEN-SECOND TAB TACKER

BY J. R. FULLERTON

Two new welding machines, designed and built by Ryan Aeronautical Co., are saving 1500 man-hours a month in little-known jobs. Called "tab tackers," these labor-saving devices attach tiny metal tabs to parts, which are soon clipped off. In the brief interim, they perform a valuable function.

Thousands of tubular parts each month which go into the production of jet, rocket and piston engines are fabricated at our plant. These are combustion chambers, ducts, rings, bands, exit shells, slip joints, collars and cones. They are made from a variety of high-temperature alloys including stainless steels, Inconel, titanium and cobalt-base metals.

The parts are cut from flat sheets of alloy, rolled, and then inert-gas tungsten-arc welded into circular form. The arc welding causes undesirable notches at the beginning and end of the longitudinal weld seam. This difficulty arises from the fact that the weld is started and ended at the edges of the sheet where there is insufficient metal surrounding these points to adequately dissipate the heat from the welding torch. As a result, the temperature rises and causes the metal in the part to melt out and form a notch.

There are two ways to overcome this objectionable phenomenon. The parts can be cut slightly oversize, so that about one-eighth inch of material may be trimmed from each edge, to remove the notches. This requires extra consumption of metal which is often expensive and in short supply. It also involves extra trimming operations and may reduce the number of parts that can be obtained from standard-size sheets.

J. R. Fullerton is Chief Welding Engineer, Ryan Aeronautical Co., San Diego, Calif.

Fig. 1 One of the tab-tacking machines which spot weld tubular sections together and attach metal tabs at the same time. Machine operates automatically

Fig. 2 Close-up of tabbed section shows how small metal squares are spot welded on to prevent the welding defects from occurring in the part itself

The other solution is to attach small metal tabs, about an inch square, to the rolled parts, at the beginning and end of the seam to be welded. Our company has followed this practice for many years. Using tabs avoids waste because they are taken from excess cut-off material or scrap. In some cases, the tabs can be blanked out with the basic outlines of the part. In other instances this is not possible because the parts are sheared or the sheet stock dimensions will not permit the extra width needed for these integral tabs.

The arc welding is then started and finished in the tab area, rather than at the sheet edges. This eliminates the undesirable notching effects. The tab metal is neatly clipped off to leave the part smooth and perfect.

Before the creation of the new machines, it was necessary to place the tabs and parts in small holding fixtures and arc-tack them together. Two to three minutes were needed to do each part. With Ryan's new tab tackers, the job is done in 10 sec, including electrode cooling time.

The equipment used is shown in Fig. 1. The upper electrode of the machine consists of a machine inert-arc welding torch, which has been modified and adapted to automatic operation. The "gun" is mounted vertically and energized by a 200-amp d-c rectifier-type welding power source. All the operator has to do to attach a tab is to insert the part into the machine and press a foot switch.

As the part goes in, it moves a lever which releases a tab from a cartridge container and drops it into place for welding. The upper welding head comes down, holding the tab and part and making the spot weld. Each spot weld not only attaches the tab but also joins the edges of the part together (see Fig. 2). Because of this facility, the machines are often used to spot tack parts into alignment when no tabs are to be attached.

High production speed is attained because the machines serve as both holding fixtures and welders and their operation is automatic. Consisting of only seven electrical relays, three condensers and one electronic tube, the control system performs an ingenious series of timed operations.

The operator starts the procedure by depressing a two-stage foot switch. First stage brings the upper electrode "gun" down against the tab and work, holding them firmly. The second stage automatically controls the welding sequence.

Argon gas is turned on and allowed to flow through the torch nozzle, blanketing the tungsten electrode and work in protective gas. Next, a high-frequency voltage is impressed which fires a spark between the electrode and the work. This spark ionizes the air gap and provides a pathway for the d-c welding current to follow. The welding current is switched on. The welding is accomplished and the current is cut off. After the arc is broken, the argon gas flows for 3 sec to protect the hot electrode and the weld from oxidation, and is then shut off. Finally, the electrode pressure is timed out and released.

The cycle takes only 10 sec from start to finish. Spot welds are uniform and sound and little adjustment is required to use the machines with widely varying thicknesses of metal.

STRUCTURAL STEEL WELDING

BY A. L. FENLASON

Joint Design

Fillet welds and simple butt welds compose 95% of most structural welding. Five percent are for special joints. It is recognized that the quality of arc-welded joints will be determined by the specific procedure used and by the ability of the welding operator to apply that procedure. Predictable results as to the physical properties and soundness of such joints can be secured only by adherence to a procedure of welding that has been thoroughly investigated. It cannot be expected that good results will be obtained even by careful and painstaking workmen if poor material and inadequate or worn-out equipment are used or if fundamentally improper methods are pursued.

Welding Procedure

Nor can the purpose of welding be obtained by the mere adoption of a carefully outlined procedure of welding if the welding operators have not been given a certain degree of training and are not properly supervised to be certain that all essential details of the specific procedure of welding are followed.

In all arc welding, the physical properties of the weld metal such as tensile strength and ductility will be determined by the particular procedure of welding that is used. The reliability of the welded joint will be determined by the degree to which that weld metal is kept free of foreign materials such as slag, grease, paint and other foreign matter and by the degree to which it is fused to the base material.

Under a fixed procedure of welding these two latter factors are the only ones under which the welding operator has control. Therefore, the welding procedure for welding should be investigated to determine whether it will produce welds with the desired physical properties.

Operator Qualification

The tests required for a welding operator are included in the investigation of a welding procedure because there have been many instances wherein failure to obtain results have been attributed to the inability of the operator when the difficulty lay in the fundamentals of the procedure. Having established that a given procedure is satisfactory, comparatively simple tests intended primarily to determine the ability of an individual to make a sound weld may then be used for the qualification of welding operators.

Let us assume then that our procedure and welding operators are qualified to produce sound welds on structural fabrication. This being the case, see Fig. 1 which shows a manual welded fillet tee joint. This type of joint is among the most commonly used and for many years manual arc welding was the best method of welding known. In more recent years other methods have been developed and qualified, as indicated in Fig. 2.

Figure 2 shows the same joint submerged arc automatically welded. Note the greater depth of penetration which is obtained by submerged arc welding. A weld of this type is produced a great deal more economically than manual welds under certain conditions.

Figure 3 shows the same type of joint welded with submerged arc semiautomatic manually operated. This method in general is faster than manual arc electrode welding; however, due to design, some joints are inaccessible with either automatic or semiautomatic equipment. This means manual arc welding must be used and the costs are, of course, higher.

A. L. Fenlason is Welding Supervisor, Consolidated Western Steel Division, United States Steel, Los Angeles, Calif.

Presented at the Jan. 20, 1955, meeting of the Los Angeles Section, AMERICAN WELDING SOCIETY.

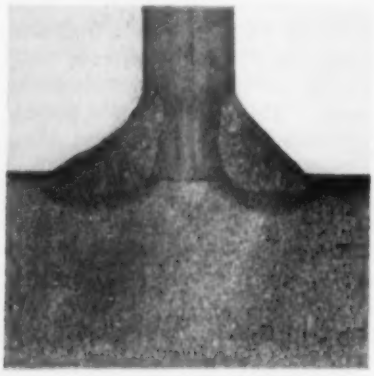


Fig. 1 Manually welded fillet tee joint

Fig. 2 Same joint as Fig. 1, submerged arc, automatically welded

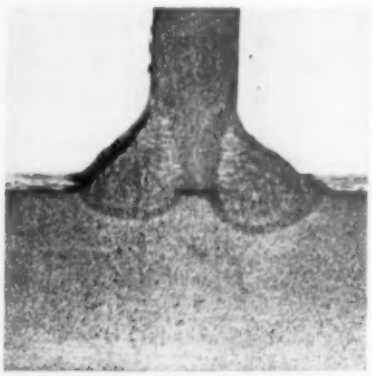


Fig. 3 Same joint as Fig. 1, submerged arc, semiautomatic, manually operated

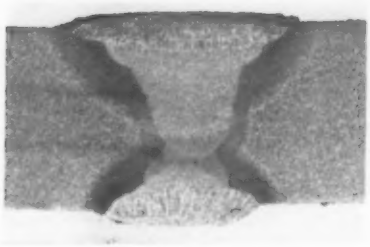


Fig. 4 Double-Vee butt weld, manually welded

Fig. 5 Same joint as Fig. 4, submerged arc, automatically welded

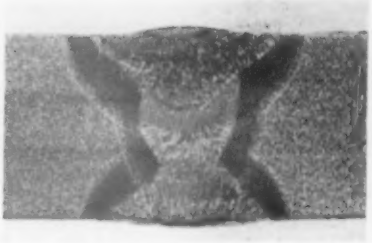


Fig. 6 Same joint as Fig. 4, submerged arc, semiautomatic, manually operated

Figure 4 shows a double-vee butt weld manually welded. Figure 5 shows the same type of joint submerged arc, automatically welded. Figure 6 shows the same joint submerged arc, semiautomatic, manually operated. It will be noted from appearances that all three welds are the same and all are satisfactory welds. However, the automatic welds are much more economically applied.

In automatic welding of the fillet welds it is generally considered good practice not to apply a weld larger than $^{5}/_{16}$ in. in a flat horizontal position. Fillet welds larger than $^{5}/_{16}$ in. should be positioned for a better appearing and sounder weld. In designing for structural steel welding, it is better, where possible, to keep the weld size $^{5}/_{16}$ in. or smaller for good economical shop operations. Sometimes, instead of using intermittent welds of $^{3}/_{8}$ or $^{1}/_{2}$ in. in size, it is better to change to a smaller size weld, make a continuous weld and, if possible, apply such welds with submerged arc automatic welding.

Inspection

The questions sometimes arise as to how a good sound weld is secured or how one is sure that the weld is a sound one. A good sound weld of course depends upon a great many variables. For most structural steel welding, reliance for integrity is based upon visual inspection. Visual inspection constitutes an important part of the practical control over the construction. It is the most extensively used of any method of inspection because it is easy to apply, is quick, is relatively inexpensive and gives very important information with regard to the general conformity of the welds to specification requirements.

Inspection starts with the material prior to fabrication. Scabs, seams, scale or many other harmful surface conditions may be detected in visual examination. Serious plate lamination may be observed on cut edges. Plate or shape dimensions may be determined by measurement. After the parts are assembled in position for welding, the inspector can note any incorrect root openings, improper edge preparation and other features of joint preparation that might affect the quality of the welded joint. Oxygen cutting irregularities and the presence of excessive scale are the other factors that the inspector should check since they too may affect the quality of the finished joint.

Visual inspection should be employed while the welding is in process. The inspector should be thoroughly familiar with all of the items involved in the qualified welding procedure.

In the application of multiple pass welding, it is very essential to inspect the first or commonly called root pass of the joint and be certain that no cracks appear, since such cracks may persist and extend to subsequent layers. Inspection of root passes offers an additional opportunity to inspect for plate laminations, since they tend to open up because of the heat incident to the welding operation.

In a case of single- or double-vee groove welds, slag from the root pass on one side of the plate drips through to form slag deposits on the other side. Such deposits should be gouged, chipped or ground out to good sound clean metal before applying subsequent weld metal.

Visual inspection is useful for inspecting the finished product with regard to such items as (1) dimensional accuracy of structure including warpage, (2) conformity to drawing requirements (this involves determination of whether all required welding has been done and whether finished welds conform with regard to size and contour), (3) acceptability of welds with regard to appearance including such items as regularity, surface roughness, weld splatter, etc., (4) the presence of unfilled craters, pockmarks, undercuts, overlaps and cracks.

The presence of defects that affect service performance and should never be allowed on the finished structure are cracks, undercut, overlap and excessive weld irregularity. To inspect for such defects, the weld surface should be thoroughly cleaned of oxide layers and adhering slag and weld spatter.

Conclusions

The facts may be summarized as follows: Assuming that the best possible design for welding is available, that the procedure has been qualified, that the welders are sufficiently skilled and trained to follow the procedure, that the welding to be performed has been covered by adequate supervision, that the equipment is in good condition, that the material has been thoroughly inspected, that fit-up with proper bevels and root opening are correct, that there is sufficient inspection to cover all of these conditions, then one may feel confident that good sound structural welding will be accomplished.

Current Welding Literature

ALUMINUM SILICON ALLOYS. Solution Rate of Solid Aluminum in Molten Al-Si Alloy, C. M. Craighead, E. W. Cawthorne, and R. I. Jaffee. J. of Metals, vol. 7, no. 1 (Jan. 1955), sec. 2 (Trans.), pp. 81–87.

BEAMS AND GIRDERS. Flame-Straightening Bent Beams, H. C. Phelps. Welding Engr., vol. 40, no. 3 (Mar. 1955), pp. 24–25.

BEAMS AND GIRDERS. Keep Your Oxyacetylene Torch Busy, J. Holt. Welding Engr., vol. 40, no. 4 (Apr. 1955), pp. 28–29.

BRAZING. Colloidal Graphite Helps Braze Powdered Parts. Precision Metal Molding, vol. 13, no. 4 (Apr. 1955), p. 59.

BRAZING. High-Strength, Butt-Brazed Joints, O. T. Barnett, N. Bredzs. Steel, vol. 136, no. 21 (May 23, 1955), pp. 114, 117.

BRIDGES, STEEL. New Record for All-Welded Construction, W. L. Doherty. Steel, vol. 136, no. 22 (May 30, 1955), pp. 74–75.

BRIDGES, STEEL. World's Largest Girders for New Cantilever Bridge, H.C. Phelps. Welding Engr., vol. 40, no. 3 (Mar. 1955), pp. 38–39.

BUILDINGS. Unique Design Used in Welded Skyscraper, M. F. Yale. Welding Engr., vol. 40, no. 4 (Apr. 1955), pp. 44–45.

COPPER. Degreasing Tanks Welded by Inert-Gas Process, H. S. Card. Welding Engr., vol. 40, no. 4 (Apr. 1955), pp. 48–49.

ELECTRODES. Inco Rod for All Welding Jobs. Mar. Eng., vol. 60, no. 6 (June 1955), p. 55.

EQUIPMENT. Automatic Hardfacing in Field Speeds Oil Well Maintenance Work, C. Swartsfager. Industry & Welding, vol. 28, no. 4 (Apr. 1955), pp. 66–68, 70–73.

EQUIPMENT. Inventive Welding Set-Ups Speed Output at Seattle Food Machinery Firm, H. E. Jackson. Western Metals, vol. 13, no. 4 (Apr. 1955), pp. 52–54.

INERT GAS. Old Gas—New Application, T. B. Jefferson. Welding Engr., vol. 40, no. 4 (May 1955), pp. 36–38.

WELDING, INERT GAS. Spot Welding from One Side—With Portable Gun, C. A. McClean. Product Eng., vol. 26, no. 4 (Apr. 1955), pp. 180–189.

IRON CASTINGS. Low-Heat Method of Welding Cast Iron, A. L. Phillips. Welding Engr., vol. 40, no. 4 (Apr. 1955), pp. 30–33; no. 5 (May), pp. 47–48, 57.

IRON CASTINGS. Low Heat Welding Saves Job. Steel, vol. 136, no. 19 (May 9, 1955), pp. 96–97.

LIGHT METALS. How Spot Welded Aluminum Makes Stronger, Cleaner Assemblies. Industry & Welding, vol. 28, no. 4 (Apr. 1955), pp. 46–47, 49.

LIGHT METALS. Spot Welding of Light Alloys, J. E. Roberts. Brit. Welding J., vol. 2, no. 5 (May 1955), pp. 193–199.

MAINTENANCE AND REPAIR. Automatic Hardfacing Cuts Welding Time 75 Percent. Industry & Welding, vol. 21, no. 3 (Mar. 1955), pp. 42–43, 75.

MAINTENANCE AND REPAIR. Built-Up Gears Outlast Replacements, A. L. Phillips. Machine & Tool Blue Book, vol. 50, no. 4 (Apr. 1955), pp. 197, 200.

MAINTENANCE AND REPAIR. Maintenance at Kitimat-Kemano, T. Jefferson. Welding Engr., vol. 40, no. 4 (Apr. 1955), pp. 34–36.

MAINTENANCE AND REPAIR. Stub Ending Drill Collars by Electric Arc Technique, W. S. Bachman. World Oil, vol. 140, no. 4 (Mar. 1955), pp. 119–120, 122, 124.

OXYGEN CUTTING. Cutting and Gouging in Shipyard, T.J. Dawson. Welding Engr., vol. 40, no. 5 (May 1955), pp. 45–46.

PENSTOCKS. On Kemano Penstocks: Welding and Controlled Low Temperature Stress Relief, M.D.E. Robinson. Can. Metals, vol. 18, no. 2 (Feb. 1955), pp. 42–44.

PROJECTION WELDING. . . Growing Importance for Automatic Assembly, R. H. Eshelman. Tool Engr., vol. 34, no. 5 (May 1955), pp. 109–118.

QUALITY CONTROL of Aircraft Welds, C. B. Smith. Welding Engr., vol. 40, no. 5 (May 1955), pp. 40–42.

RAILROADS. Faster Railbonding. Welding Engr., vol. 40, no. 5 (May 1955), p. 56.

RESISTANCE WELDING May Be Answer, T. F. Hruby. Steel, vol. 136, no. 22 (May 30, 1955), pp. 70–72.

SHIPBUILDING. Choice of Electrodes in Welding of Ships, G. Zoethout. Instn. Engrs. & Shipbldrs. in Scotland—Trans. vol. 98, pt. 3 (1954–55), pp. 85–102 (discussion), pp. 102–104.

SOLDERING. After 2000 Years Soft Soldering is Still Growing in Fabrication Usage, E. A. Lancaster. Can. Metals, vol. 17, no. 13 (Dec. 1954), pp. 43–44, 46; vol. 18, no. 1 (Jan. 1955), pp. 43–44, 46–47; No. 2 (Feb.), pp. 48, 50–52.

STAINLESS STEEL. Welding Cracks in Columbium-Bearing Stainless Steel. Metal Progress, vol. 67, no. 5 (May 1955), pp. 109–111.

STEEL CASTINGS. Cast-Weld Construction of High-Alloy Steel Parts, G. J. Gibson. Product Eng., vol. 25, no. 12 (Dec. 1954), pp. 178–183.

TANKS. Mechanized Tank Production Pays Off, G. Bain. Am. Mach. vol. 99, no. 11 (May 23, 1955), pp. 145–147.

TESTING. Assessment of Spot-Weld Quality by Torsion Test, P. Joumat, J. E. Roberts. Brit. Welding J., vol. 2, no. 5 (May 1955), pp. 225–233.

TESTING. Inspection and Testing of Welds in Ships and Pressure Vessels, B. P. Fielden, E. B. Suters. Australasian Engr. (Feb. 1955), pp. 65–75.

TITANIUM Fabrication Study. Light Metal Age, vol. 13, no. 3–4 (Apr. 1955), pp. 16–17, 25–30, 38.

TITANIUM. Production Line Methods for Welding Titanium, L. Barrett and H. D. Justis. Industry & Welding, vol. 28, no. 4 (Apr. 1955), pp. 40–43, 76–77.

TOOLS, JIGS AND FIXTURES. Welded Jigs Retain Tolerances Without Stress Relieving, D. S. Geroukl. Industry & Welding, vol. 28, no. 4 (Apr. 1955), pp. 79–80.

TUBES, ALUMINUM. Automatic Production of Rolled and Welded Aluminum Tubing, R. Thompson. Light Metal Age, vol. 13, no. 3–4 (Apr. 1955), pp. 12–14.

WELDING. Examination of Fusion-Welding Processes Suitable for Vitreous Enameling, B. Trehearne. Sheet Metal Industries, vol. 32, no. 337 (May 1955), pp. 361–362.

WELDING. Low Heat Joining Saves Tools, A. L. Phillips. Tool Engr., vol. 34, no. 5 (May 1955), pp. 85–87.

WELDING Developments in Germany, I. C. Fritz. Welding & Metal Fabrication, vol 23, no. 5 (May 1955), pp. 169–176.

WELDING. Machining Before Welding, P. G. Lessman. Product Eng., Vol. 26, no. 3 (Mar. 1955), pp. 186–188.

WELDING MACHINES. Mechanized Argon-Arc Welding, G. D. Chapman. Light Metals, vol. 18, no. 205 (Apr. 1955), pp. 115–121.

WELDING MACHINES. Spot Welding of High-Tensile Steels, P. Joumat. Sheet Metal Industries, vol. 32, no. 337 (May 1955), pp. 357–360.

WELDING VS. CASTING. Substitute Weldments for Heavy Castings. Industry & Welding, vol. 28, no. 4 (Apr. 1955), pp. 109–110, 112–113.

WELDABILITY. Further Examination of Welding and Tensile Properties of Some Al-Zn-Mg Alloys Containing Copper, W. I. Pumphrey, D. C. Moore. Brit. Welding J., vol., 2. no. 5 (May 1955), pp. 206–215.

WELDING RESEARCH. Automobile Engr. vol. 44, no. 12 (Dec. 1954), pp. 569–574.

ZINC ALLOYS. How to Weld Pot Metal, H. Kerwin and K. Kerwin. Welding Engr., vol. 40, no. 4 (Apr. 1955), pp. 25–27.

Society News

AWS Spring Meeting and Show Hailed as Outstanding Success

Latest Advances in Welding featured at 1955 Spring Technical Meeting and Third Welding Show held in Kansas City, June 7–10

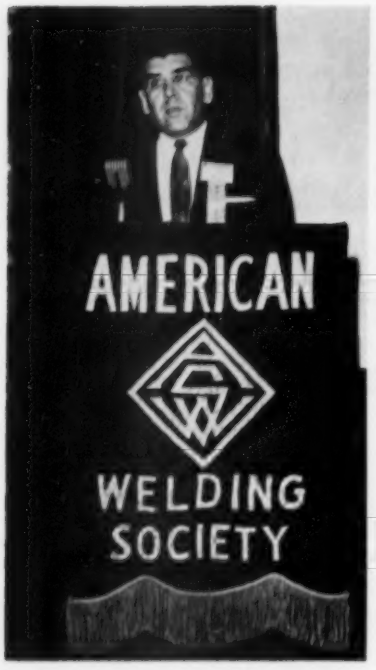
If the measurement of a successful welding convention is the sum total of a beautiful, well layed-out exposition of the most modern welding machines, equipment apparatus and supplies, the finest portfolio of interesting, data-packed technical papers, all well presented, a live-wire series of practical welding conferences, a fast-moving social program that kept everyone hopping and in good cheer, and an appreciative, interested and cooperative member audience and attendance for each and every session, then the Kansas City Arrangements, the National Convention, the Exposition, and the Technical Papers Committees can look back and say—"we did it at K.C!"

The 1955 Spring Technical Meeting and Third Welding Show constituted one of the largest and most successful National Meetings and expositions ever held by the AMERICAN WELDING SOCIETY. Over 5000 technical, management and production men registered to attend the varied activities conducted during the four days. Over 7000 were clocked passing through the entrance gates of the Auditorium. There were 950 registrants at the Technical Papers Sessions. The attendance came from everywhere in America and a number from Canada and overseas.

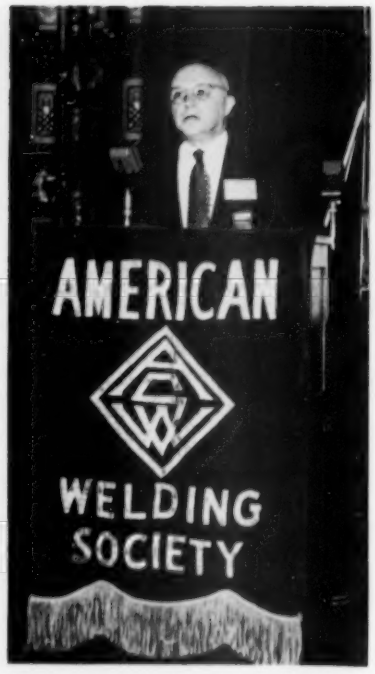
Featuring the National Spring Meeting were 13 technical sessions, where some 41 papers on all phases of welding activity were presented.

The Welding and Allied Industry Exposition, held concurrently with the Spring Meeting, was the largest in AWS history. Engineers, designers, technical managers, metallurgists and production men from throughout the United States and abroad visited the Show to see the latest developments in welding equipment, accessories and materials.

Even before the Kansas City Convention and Tourist Bureau girls could powder their noses and limber up their typewriters, members and guests besieged the Registration desk at the Hotel Muehlebach, to book their passage for the activities of the coming four days. Lee Page, in charge of Hospitality, helped to keep them happy. Comparable lineups, starting Wednesday noon, were to be seen at the Auditorium for the Welding Show. They came from far and wide



In the "Opening Session" on Tuesday morning, President J. H. (Joe) Humberstone sparked the get-a-way with his "official" welcome to the AWS 3rd National Spring Meeting and Welding and Allied Industry Exposition



At this same session, First Vice-President J. J. (Jack) Chyle capably reviewed the highlights of the technical program to be presented during the next four days

The "Opening Session" was well attended, indeed. During Mr. Chyle's review, nearly everyone got out their programs and made notations against the various listings in line with his comments. All of the technical sessions during the days following were crowded with equally interested members and guests

Four hundred persons attended the Welding Conferences held in conjunction with the Welding and Allied Industry Exposition. These conferences, organized for the first time this year, featured subjects of wide general interest.

Two inspection trips to industrial plants in the Kansas City area added to the week's activities.

The major social function of the meeting was the "western party and barbecue" held on Thursday evening, June 9th, under the sponsorship of the AWS Kansas City Section. Other principal activities included the President's Reception in the Grand Ballroom of the Muehlebach Hotel on Tuesday evening, June 7th, and a Sustaining Members Luncheon on Thursday noon. The Board of Directors met on Wednesday, June 8th, and the Annual Business Meeting was held on the afternoon of the same day.

The Ladies' Program, which proved to be one of the most diversified and attractive functions ever sponsored for the fair sex, included several sightseeing tours and trips to points of unusual interest in Kansas City.

To top it all, the weather was fine. Some had feared that Kansas City was going to be hotter than hot, might get a tornado, might get a flood, and four, five or six other mights! Not one of these big black giants materialized. It was cool enough for everyone to wear their coats. The tornadoes stayed in West Kansas. And the floods stayed far, far away.

Addresses by Humberstone and Chyle Mark Opening of Convention

The official activities for the week got off to an auspicious start on Tuesday morning in the Grand Ballroom of the Muehlebach Hotel, when President Joseph H. Humberstone delivered his "Keynote Address" and First Vice-President John J. Chyle presented a "Digest of the Technical Meeting Papers."

The use of welded products, President Humberstone pointed out, is increasing at a phenomenal rate in excess of what could be expected from the general rise in business activity.

"This means," he said, "that the greater utilization of welding is related not only to general economic conditions conducive to growth in any field, but that developments within the welding field itself have stimulated the expansion rate in excess of the over-all expansion increased in industry."

Vice-President Chyle emphasized that, taken as a whole, the excellent papers on the agenda reflected the latest information on welding gathered in manufacturing plants, educational institutions and private and public laboratories throughout the nation.

The full text of both of these major talks will be found in later sections of this story. Don't miss getting the full details!

Technical Papers Program

As Vice-President Chyle so ably described, the Technical Papers Program included papers dealing with the economics of welding, and the welding of the newest engineering materials, such as titanium, molybdenum and the new special tempered steels for pressure vessels. Other papers presented latest information on the newer welding techniques, such as carbon dioxide welding,

use of iron powder electrodes, and procedures for obtaining extraordinarily high electrode deposition rates with coated electrodes, inert-gas consumable electrodes and submerged-arc-welding processes.

New developments in brazing alloys containing lithium, the high-speed welding of light gage materials, surfacing with composite tube rods, and welding and cutting radioactive process equipment were the other subjects included in the technical sessions.

Welding and Allied Industry Exposition

One of the most fruitful efforts ever staged by the SOCIETY, the Third Welding Show, brought the practical story of the art and science of welding to still another area of the country—Kansas City.

Known as the "Heart of America," the site drew visitors from all parts of the country and Canada, as well as many foreign countries.

The show held in the Municipal Auditorium, was the first where displays were laid out in a free-flowing pattern for audience traffic. Many exhibitors took advantage of the layout to use larger exhibit areas and virtually all had their equipment in action during the three days of the exposition.

Hundreds of new products were shown by the 90-odd companies. The exhibits were highlighted by the emphasis on automatic operation of almost every type of welding equipment. Visitors who had attended the two previous shows commented upon the rapid advance in such automatic processes as being the outstanding development of the past two years.

A number of university engineering students took advantage of the opportunity to attend both the exhibits as well as Spring Meeting sessions.

One section of the show was devoted to products produced by welding by manufacturers in the Kansas City area. Thirteen companies submitted their products for the inspection of visitors. A special section of the exhibit floor was devoted to these products and they were displayed with dramatic spot lighting, colorful booth backgrounds and explanatory pictures and charts.

Kansas City had never before witnessed an exposition of the kind which appeals broadly to all metal-working industries. The drayage company reported that the total weight of equipment set a record for the hall and the electrical supply company noted a similar record in terms of total kva's supplied.

Welding Conferences

The Welding Conferences, designed to attract additional visitors to the

Even "wild and wooly K. C." went "formal" on Tuesday evening for the President's Reception. Nearly six hundred members and guests came through "the line," extending their greetings to the National and Section Officers and their wives. Shown here as part of the Receiving Line are President and Mrs. Humberstone, First Vice-President and Mrs. Chyle and, partially hidden, Second Vice-President and Mrs. Sander

After the Receiving Line "broke," everyone relaxed. Here our photographer caught Frank Mooney, Assistant Secretary, in good company with President "Joe" Humberstone, Second Vice-President "Sandy" Sanders and Exposition Chairman "Harry" Rockefeller

AWS was honored by a group of distinguished guests. Here, we caught "Bill" Rice, past-president, "Bob" Fernley, secretary-treasurer, "Jim" Alcock, past-president and "Ed" Caluwaert, president, all of the National Welding Supply Association, planning the date for their 1956 NWSA Convention in New Orleans

The AWS Presidential Row was snapped at a time when "Jack" Chyle (1st VP) was telling a story to "Sandy" Sander (2nd VP), "Joe" Humberstone (Pres) and their wives

One of the distinguished guests, President William (Bill) Bernard (right) of the Australian Institute of Welding is here caught while telling Secretary "Joe" Magrath and Exposition Chairman "Harry" Rockefeller a tall tale from "down under"

The Kansas City folks certainly earned a relaxing moment after seeing that their work was rewarded. "Jim" Kirk, "Brick" Singleton, "Blaine" Harrington and "Jim" Blake of the K.C. Arrangements and Section Officer groups, with their ladies, are having an animated chin-fest

Our foreign visitors thoroughly enjoyed the Reception, too. Bjorn Fjelle from Oslo, Norway (second from left) and Bo Appelstam from Stockholm, Sweden (end, right) seemed to be in friendly and jovial good company

Welding Show, were held in the Little Theatre at the Municipal Auditorium. They were conducted as panel discussions.

The Wednesday afternoon Conference was a "Practical Welding Clinic" at which maintenance and repair men from the engineering level down to the welder received practical information on how to solve specific welding problems. A. A. Wald, Caterpillar Tractor Co., covered maintenance and repair welding in the large plant; S. R. Joslin, Contractor's Service and Hardfacing Co., discussed job shop welding problems; and J. H. Forrer, North Dakota State College, described the repair welding of farm implements.

The second Conference, "Welded Plastics—A New Field for Welding," provided an up-to-date account of the status of this relatively new and fast growing area of welding. The paper by R. C. Trudeau, D & R Plastic Welders, Inc., described the latest methods and equipment for welding plastics. F. J. Bockhoff, American Agile Corp., described many unusual applications of welded polyethylene, while A. H. Henning showed where welded polyvinyl chloride was being used to advantage. Some of the products described by these two speakers included blowers and fans, storage tanks and containers up to 60 in. in diameter, and large pipes and duct work in chemical and process industry plants.

The third Conference was concerned with "Automation in the Welding Industry." The first speaker, F. S. Parker of General Electric Co., discussed the various concepts of automation and showed to what extent these concepts are being applied to welding operations. P. G. Parks, Solar Aircraft Co., described the trends of automation in the aircraft engine industry with particular emphasis on inert-gas-shielded arc welding. How automation is being applied to welding in large production setups was illustrated by J. F. Randall, Ford Motor Co. He described the resistance welding equipment and materials handling techniques used in the Ford plant. A number of fixtures and positioners specifically designed for automated welding were described by

A. Pandjiris of the Pandjiris Weldment Co.

Other Activities

Lack of space in this issue of THE WELDING JOURNAL prevents our saying very much about the many other extremely well conducted, enjoyable and profitable activities such as the President's Reception, Board of Directors Meeting, Annual Business Meeting, Sustaining Members Luncheon, Barbecue and others. However, the accompanying picture story will give those who had to stay home a high spot review of what happened.

A Grand Experience!

No doubt about it, this Kansas City Meeting was one of the finest affairs ever sponsored by the AMERICAN WELDING SOCIETY. It was, truly, a grand experience for all. Much of the credit, of course, goes to the local AWS Kansas City Section, our hosts, who spared no efforts in doing such a tremendous job.

We are happy to add that at National Headquarters letters are still coming in from Exhibitors extolling the fine cooperation they received from Kansas City subcontractors, and from members and guests complimenting all concerned on what they claimed was one swell convention.

Successful conventions just do not happen. It takes a lot of planning, and a lot of work. At least one whole year for some of the people involved, and more for others. For instance, work is now being done on conventions as far advanced as 1960—believe it or not.

Next: Philadelphia in October 1955 and Buffalo in May 1956—See you there!

There's lots of "behind-the-scenes" work in a convention. The first thing each morning, all the authors and supervisors of the day are routed out early for breakfast where, with their ham and . . ., they are acquainted with the A, B, C's of the day's routine. "Cecil" Poarch (standing, second from right) was in charge of the arrangements

Meanwhile, our charming ladies attended a number of activities and luncheons arranged for them by the K. C. Ladies Entertainment Committee, Chairmanned by "Bob" Bennewitz (lucky fellow) who, somehow, missed a fine opportunity to get into a swell picture!

Keynote Address

By J. H. HUMBERSTONE

President, American Welding Society

To all who have the good fortune, and—might I say—the good judgment, to be in Kansas City at this time, I extend a warm welcome on behalf of the AMERICAN WELDING SOCIETY. May your experiences during the next four days prove once again how inseparable good business and pleasure can be at a welding show.

For certainly there will be many things to do which should be both enjoyable and profitable—meeting old friends and making new ones, listening to technical papers on the latest developments, learning about the most recent and advanced research, and about down-to-earth practical accomplishments which increase production and reduce costs. You will see one of the largest assemblages of welding equipment and accessories ever gathered under one roof.

If the program of technical papers, discussions and demonstrations achieves what I believe it will—along with all the profitable informal sessions which grow out of the various social occasions which have been planned—all of us will leave with a quickened sense of the history, the accomplishments and the future of the welding industry. We will, in short, be better equipped to do a better job for our respective companies and the various segments of American industry we serve.

We expect a record attendance at this meeting, not only because of the program we have planned, but because Kansas City is at the center of a huge concentration of industry and offers a wonderful combination of markets and certainly excellent facilities for a show of this kind. Therefore, the Manufacturers Committee of the AMERICAN WELDING SOCIETY is to be congratulated on its selection of Kansas City for our third All-Welding Show and Allied Industry Exposition. This occasion is

During all this time, big things were happening at the Auditorium. On Wednesday morning, President "Joe" Humberstone, with experienced skill and a sure touch, quickly cut the entrance chain, marking the Official Opening of the 3rd AWS Welding Show

Some ninety-odd Exhibitors displayed the latest welding machines, positioners, metals, equipment, apparatus, supplies and supplemental facilities to thousands of registered attendees. This general view gives an idea of the size of the displays in the center hall only

made still more important in that the SOCIETY—having decided to hold its Annual Meeting in the Spring—is doing so for the first time here.

Besides giving us plenty to do, a convention like this also affords us a pause—both satisfying and necessary—in our normal routine. An occasional pause is necessary in order to appreciate more fully how far the welding industry has come and how far it is going.

Here in Kansas City we stand in the midst of development and growth. In a large historical sense, when we think of the limitless future, we are standing at the very beginning of things.

New concepts of power—jet propulsion, atomic fission, thermonuclear fusion—invest greater significance in every thing we do. Tools, processes, procedures and materials have become more complex.

Along with new basic concepts of power, there are many significant developments which lay great stress on basic and applied research: the growth of electronics, the development of new elements like titanium and zirconium, and the trend toward automation.

There has been, as we all know, a tremendous upsurge in industrial interest in atomic energy. We have all heard of, and read about, the atom-powered submarine, the first commercial electric plant powered by atomic energy, and now the atomic plane—a project with a testing target date set for 1957.

The relationship of the welding industry to the fact of atomic energy is not so remarkable as it is necessary. Without welding, I doubt that the development could have come along at this time. We are directly and indirectly involved with atomic projects in

The Show audience came from far and near and kept exhibitor booth attendees busy with answering questions—technical, practical and mechanical—but *all* welding! Everyone, exhibitor and visitor, went home satisfied that no finer welding show had ever been staged. All were rewarded for time, effort and money expended

many different ways. The engineering problems are tremendous. We are on the threshold of a vast new era which will see—in generations to come—industry as we now know it—revolutionized and the world transformed.

Along with basic and applied research on ambitious projects of a pioneering nature, there are programs for the improvement of the quality, economy and operation of standard tools. Established inert-gas-shielded welding processes are moving into new areas which have been, until recently, economically prohibitive.

To indicate how fast things are moving, seven years from now—I am told—more than half of the electronics business will be devoted to devices that do not now exist. This suggests again the tremendous potential growth in the use of welding tools and techniques for the production of electronic components alone. Mechanized production methods in the field of brazing are becoming increasingly essential for both quality and speed.

We can take pride in the fact that the welding segment of American industry is proving itself equal to the new production requirements based on increased mechanization, the growing use of electronic controls and automation.

In the matter of welding speeds, for example, industry is demanding more every day. Recent progress in high-speed welding on light-gage material with submerged arc and inert-gas-shielded arc processes has established conditions which now enable users of these processes to gain optimum results.

We have been hearing a lot lately about "automation." We will be hearing a lot more about it in the future because—roughly—50% of the cost of production lies in materials handling.

Welding, which was fundamentally a "hand" industry in the beginning is, as we all know, being modernized into machine and fully automatic operations. Beyond this, the challenge of automation will require from us a still broader approach to our welding and cutting processes. The process itself must be considered and developed in relation to its adaptability to automation setups if we are to take a strong part in this significant, cost-saving industrial trend.

With the exception of resistance welding, the fusion welding industry has not been in a position to give users a complete package—jigs, fixtures, mechanisms for automatic feeding and rejection. Welding and cutting experts are finding it necessary to know more about jigs and fixtures, while jig and fixture experts have to know more about welding and cutting processes, and all of us will have to know more about automation as time goes by.

Our program this week includes a symposium which will treat with the highly controversial topic of qualification requirements for welding. Reflecting the fundamental thinking of the AWS Committee on Standard Qualification Procedure, the discussions will start with the basic philosophy influencing qualification and follow with the application to carbon and alloy steels, the inclusion of nonferrous metals, and the extension to resistance welding and brazing. Finally, the application of the principles to new processes will be covered.

In general, the symposium will treat the problems of qualification from the fundamental approach. It will raise such questions as: "Is qualification always necessary and, if so, to what extent?"; "What is the significance of welding qualification in the over-all picture of quality control?"; "What part does the operator play?" Thus the symposium will provide an opportunity to re-evaluate the whole problem of qualification.

I see no need at this time for further comment on technical matters, except to say that committee work of the American Welding Society lies at the very root of progress in welding, for the American Welding Society is not a passive organization; it is a stimulating force.

An institution, to be truly alive and vital, must be an active and growing organization. It goes without saying that it needs a growing membership and a dynamic philosophy.

To me, the idea of an institution carries with it a suggestion of immortality. It is a method of transmitting from generation to generation the progress we make on the things we create—our good works, our hopes and our goals. This is true of a family, a business, an industry and an organization like the American Welding Society.

Among the stated objects of the Society, as set forth in Article II of the Constitution and By-Laws, is reference to "fostering public welfare and education, aiding in the development of the country's industries and adding to the material prosperity and well-being of our people."

I did not come to Kansas City to give a sermon—and certainly no one came to the welding show to hear one. But we should never hesitate—even at the risk of being considered social philosophers—to speak out on themes which identify our industry with the welfare of the American people.

In doing this we simply join various leaders of American industry who recognize—and say—that social wisdom must match scientific progress.

Let this acknowledgment be an ingredient in the philosophy of the American Welding Society. Let it be a part of our every day thinking as we go about the important business of doing a good job for our respective companies and the various segments of American industry we serve.

A Review of Spring Technical Meeting Papers

By JOHN J. CHYLE

First Vice-President, American Welding Society

I am very happy to tell you that this year's technical program is up to par and up to the usual high standards of the past. This year's program should be of still greater interest than those we have had, due to some outstanding developments which will be reported.

First of all, I would like to congratulate the chairman of the Technical Papers Committee, Dr. R. D. Stout, and the Secretary, B. E. Rossi, and their staff for an outstanding job in selecting, preparing and organizing this year's Technical Papers Program.

The technical papers which will be presented will reflect some of the latest and most up-to-date information that has been gathered in the various laboratories, both public and private, manufacturing and industrial plants, and educational institutions throughout the entire nation. Some of this information is so new that it may be, figuratively speaking, "hot off the griddle."

I am sure that the money expended in obtaining this information would run well in to the millions of dollars, and this is available to you at the price of membership in the AWS.

The technical papers that will be presented and discussed will include the results of both basic and applied research investigations.

Basic or theoretical research differs from applied or development type of research primarily in the objectives that

are being sought. Theoretical or basic research has for its objective the determination of scientific facts and to record them for what they are worth. These facts may or may not have any bearing in the solution of a problem, but do give information of an abstract nature.

On the other hand, applied research has for its objective the solution to a problem or the development of a process or procedure. In this case we have in mind a practical or commercial end return.

While many technical discoveries are made as a result of a "trial and error" or empirical method of experimentation, it is most important that basic research be also carried out at the same time. Basic research is the backbone and the accelerator in technological developments.

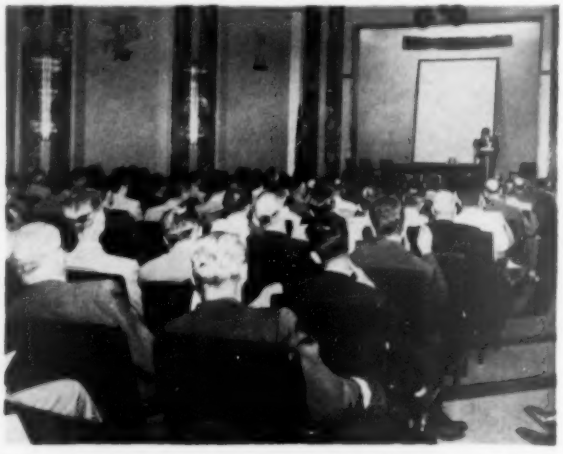
This year the Technical Papers Committee did an outstanding job in preparing a well-balanced technical program that contains both basic and applied research. Therefore, these technical meetings will be of interest to all types of welding people, whether they be interested in basic research, applied research, manufacturing, sales or whether they are involved directly in welding operations.

Our technical program will consist of the presentation of technical papers in 13 sessions and over 40 papers will be presented in these sessions. It will, of course, be impossible to digest each and every one of the 40 papers which will be presented, but I will attempt to describe some of the more recent developments and those papers which may be of greater interest to you.

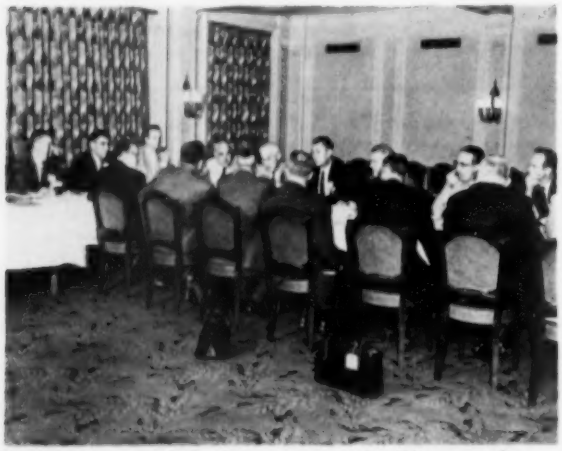
My purpose in this morning's session is to serve as a guide to assist you in your over-all examination of the very worthwhile program which your Society has prepared for you here at Kansas City.

While my chore was to digest all of the papers that are being presented at this Third Session, the thought occurred

Manning the Membership Promotion Booth at the Municipal Auditorium were some of the top-notch officers of our Society. Here, "Ed" Dato, National Membership Chairman for the 1954–55 fiscal year, shows a pertinent item in the May issue of The Welding Journal to "Joe" Humbert, a prospective member. "Joe" became a Member! "Phil" Blake, chairman, Kansas City Welded Products; Clarence Styer, director of District No. 11; and Lyell Wilson, Board Member helped close the "sale"



Tried for the first time were Welding Conferences at the Exhibit Hall. Designed to attract more visitors to the Show, they proved to be an unquestioned success. Hundreds attended the three-day sessions and the panelists were warmly received



Business, as usual, had to go on. As this was also an Annual Meeting of the Society, a meeting of the Board of Directors was convened, at which twenty-two Board Members conducted the business on a large agenda. Only a portion of the long table grouping could be shown in our picture

There is always a strong member and guest interest in plant visits, for satisfying the desire to see how someone else does the job. The folks who came to Kansas City were no exception; large numbers attended plant inspections on both Wednesday and Thursday

to me that your interest might lie in several different directions, for which fortunately we have the printings and scope of all phases of arc welding presented here in Kansas City.

Each of you have been sent here by your companies, or have come under your own resources, because you are interested in welding.

It is extremely difficult for any one individual to be interested in all phases of welding; therefore, I would like to present to you my version of the categories under which these papers might be grouped. I would suggest that you follow my outline using your own programs as a guide and I will attempt to highlight some of these papers and segregate them into the categories in which they fit and thus perhaps assist you in determining which papers will be of best advantage to you and your company.

My impression is that the technical papers being presented here may be classified in the four categories which I will now mention.

1. Papers which present advancement or progress in welding knowledge.
2. Papers that deal with the economics or cost of welding.
3. Papers which present new information in the testing of welds.
4. Papers which deal with the development of new materials that are available now for welding.

1. Papers Which Present Advancement or Progress in Welding Knowledge

First of all, the Technical Papers Committee has given considerable space to the presentation of the developments in the field of inert-gas-arc welding by devoting two sessions, 1 and 4, with a total of 14 papers.

These welding processes have assumed tremendous importance within the last few years because of their application now to not only the special metals but also because of their application to the welding of carbon and low-alloy steels.

There have been some interesting new developments in the field of inert gas welding. At one time the inert-gas consumable-electrode process was direct-current reverse polarity. With the developments that have been made today, it is now possible to use a-c welding current as well as d-c straight polarity for inert-gas arc welding with the consumable-electrode process.

These developments have been brought about by some fundamental studies of a basic nature on the effect of activating the surface of the wire.

A paper on basic development of considerable importance is one entitled "Electrode Activation for Inert-Gas-Shielded Arc Welding," to be delivered in Session 1.

Studies have indicated that the addition of certain metals and oxides to the surface of the welding wire has been found to produce marked changes in the deposition rate, mode of transfer and alternating current stability of the welding arc. At one time only direct-current reverse polarity welding was considered possible in using the consumable-electrode inert-gas arc-welding process.

This paper will also describe the theory of cathode activation and the techniques for producing activated wire for inert-gas arc welding. The techniques for producing activated electrodes will be presented.

Why is this important?—Because it will help reduce arc blow on some applications and also widen the field of power sources as well as effect economies in electrical power consumption. It will result in economies in carbon steel welding.

Another paper along similar lines is on the subject of "A Straight-Polarity, Inert-Gas Process for Welding Mild Steel," to be given in Session 4.

The use of straight polarity in the consumable-electrode process for welding mild steel will be described. Advantages of higher deposition rate and characteristic of the straight polarity arc will be discussed.

This new development has been made possible also by the application of a coating to the surface of the electrode to stabilize the arc.

A brief discussion of arc stability and other arc characteristics will be included.

Applications of this process and weld characteristics, such as speed, penetration, bead contour and porosity, will be described.

The cause for porosity in some inert-gas arc welds in steel will be explained in a paper entitled "Some Fundamentals of Inert-Gas Arc Welding," which will be given in Session 1.

The effect of dissolved nitrogen in steel weld metal will be described. It has been found that not all of the nitrogen absorption by the molten weld metal is retained.

As the weld metal cools and freezes, nitrogen is released to form porosity. The porosity, found to be detrimental, is encountered when nitrogen to the extent of 1% is present in the argon arc welding atmosphere.

This data, therefore, explains the reason for the high argon purity requirements in the application of that gas to the shielding of steel welding arcs.

Another paper of considerable interest is "Maintenance Welding and Cutting Operations on Radioactive Process Equipment," which will be given in Session 6.

This is a new subject for the welding engineer in which hazards never before encountered must be considered. Where maintenance and welding repair are required in atomic energy facilities the relative cost is very high when compared to the same operations under normal conditions.

When repair welding on parts which are radioactive, radiation tolerance levels are known and work intervals are established and severe controls must be imposed. Safety of personnel is paramount in consideration and the records at the Hanford Atomic Products Operations have indicated that this extreme care, which has been exercised, has resulted in no difficulties from the standpoint of injuries.

Detailed preparations using protective clothing and devices, timed movements and rehearsed operations protect personnel and insure success of the specific maintenance welding operation. Some modification of existing welding equipment and techniques is indicated in order to overcome the problems encountered.

Types and kinds of radiation and

There were many things to see including the welding of jet engine components at the K.C. Aviation Gas Turbine Division of Westinghouse (above). Two plants of the Sheffield Steel Division, Armco Steel Corporation, were also visited

At a special luncheon of AWS Sustaining Members, President Humberstone tendered a special report covering the Society's activities, the things it aspires to do and the ways and means required to do those things that should be done. His excellent talk is reproduced in full in this issue—read it!

Finally, near the end of the business of four full days came the time for a period of relaxation, well planned and supervised by "Jim" Kirk of the K. C. Arrangements Committee, at the famous Saddle and Sirloin Club. Chartered buses, laden with "refreshments," brought nearly four hundred thoroughly happy people to the event

methods of decontamination are briefly discussed.

The information on this subject may well become a very important phase in future maintenance welding and cutting operations on radioactive process equipment.

Because of the vast interest in power plant applications of atomic energy, this subject is of extreme interest to those people who are going to be involved in this type of operation.

One of the new approaches in understanding the effect of the I^2R heating in the electrode wire is described in the paper "The Effect of I^2R Heating on Electrode Melting Rate," which will be presented in Session 11.

Here is a new theory confirmed by experimental data in which the concepts of I^2R heating in an electrode extension can be applied generally to coated electrodes, inert-gas consumable electrodes and submerged-arc-welding processes. This approach shows a limiting current density for uniform melting of coated electrodes and an interrelationship between electrode extension and melting rate for inert-gas consumable-electrode and submerged-arc welding.

This new concept explains some of the phenomenal results that have been obtained in the deposition rate in the inert-gas consumable-electrode arc-welding process as well as in the submerged-arc-welding process. Extraordinary high-melting rate depositions have been obtained which can be explained by the I^2R heating effect in the welding processes described.

2. Papers That Deal with the Economics or Cost of Welding

I will now go to my second grouping of technical papers to papers that contribute to the economics or cost of welding.

Under this section a paper "Carbon-Dioxide-Shielded Consumable-Electrode Arc Welding," given in Session 4, is of utmost interest.

One of the most recent developments is the use of CO_2 gas for shielding in the consumable-electrode arc-welding process. This paper will describe the characteristics of the CO_2 shielded arc and the relation of the weld metal chemistry to welding conditions. Typical mechanical properties will be presented and the cost of using CO_2 gas will be discussed.

The use of CO_2 gas may well be a new epoch in the progress of the welding industry. The cost of gas-shielded arc welding is tremendously reduced by substituting CO_2 for argon or helium. This substitution modifies the characteristics of the arc and weld metal. It undoubtedly will have an exceptionally wide range of application in the field of steel fabrication and can probably be applied to the commercial grades of steel now being fabricated by other welding processes.

Why is it of interest? Primarily because of its low cost, deep penetration, visible arc, no cleaning necessary, pleasing bead appearance, and high metal deposition rate, 30 lb per hour or more. This new process has been in commercial production use for some time.

Another paper in the field of inert-gas welding is the one entitled "Consumable-Electrode Inert-Arc Spot Welding," which will be given in Session 4.

The field of inert-gas arc spot welding has rapidly expanded and has to some extent encroached on some of the resistance-welding processes, such as spot welding. This new process is of considerable interest because of its economy in equipment costs and the paper on this subject will include a description of the process, its advantages and limitations, its field of applications and its range of usefulness in terms of material, type and thicknesses. The equipment and specific applications, as well as other possible uses, will be indicated.

Another paper on "High-Speed Welding of Light Gage Material" will be presented in Session 9, which will describe the recent progress in the field of high-speed welding with submerged melt and inert-gas-shielded arc processes.

This is a new field for these processes in which the conditions for welding of light gage material will be described and a number of specific applications will be discussed in detail.

This high-speed welding is generally associated with automatic welding where a very high speed can be readily obtained.

This may be considered a new field for these welding processes—where automatic welding plus proper fixturing will reduce welding costs.

A list of other papers of interest under my grouping of weld economies may be the following:

(*a*) "Inert Gas Welding in the Aircraft Industry," Session 1.

President "Joe" and Mrs. Humberstone were the honored "first-in-line" at the Barbecue. Plates were heaped with barbecued beef, pork, lamb and *all* the fixings. "Go Western" and "relax" were the order of the evening

It was rough and tumble, no holds or puns barred, and plenty for all, in a good fellow atmosphere. If the hair was up, it was soon let down. No speeches and no technical problems

(*b*) "Surfacing with Composite Tube Rod," Session 9.

(*c*) "Inert-Gas Consumable-Electrode A-C Welding of 4130 Steel," Session 8.

3. Papers Which Present New Information in the Testing of Welds

My third grouping is on papers which present new information in the testing of weld and weld metal.

In the investigation of the causes of weld cracking some important data and information have been obtained recently which promises to aid in the solution of many of the weld cracking problems encountered in high-strength, low-alloy steel welds.

A paper on this subject, "Investigation of Weld Metal Cracking in High-Strength Steels," which will be presented in Session 5, will describe a special apparatus developed to study the basic causes of cracking in high-strength weld metals.

Hot-tension properties of selected high-strength weld metals were determined during cooling down from the molten state. The hot cracking resistance of those same steels were studied, not only in relation to composition variables, but in relation to each other. Particular emphasis was placed on a quantitative study of carbon, sulfur and phosphorus variations and rare earth additions in SAE 43XX type weld metal deposits.

This is a new approach to establishing causes for "hot-cracking" of welds and of course is of great importance to the aircraft industries.

Of particular interest, also, is a paper on "Weld Metal Flaw Evaluation Studies," which will be given in Session 5.

This paper deals with the weld metal flaw evaluation studies in which the special testing apparatus is a sphere approximately 9 ft in diameter made from $^3/_4$-in. high-strength, low-alloy steel with good notch toughness.

The test specimen is a 24-in. diam circular disk of ship-plate steel which is welded into, and is part of, the wall of the sphere. The test disk has the same thickness and contour as the wall of the sphere and contains full-size welded butt joints in which various welded flaws of controlled size are located.

The tests indicate that static loading is an excellent way to evaluate flaws.

This is a new approach to weld testing and may indicate that this static loading may give results not obtainable by the ordinary test methods.

Another paper in the field of testing of weldments is the one on "Static Tests of Arc-Welded Aluminum Alloy Beams" to be given in Session 6.

Simple beam tests were performed to obtain design information by comparing the performance of I-beams fabricated from aluminum alloys 5154, X5356 and 6061. These alloys are currently of prime importance for use in welded structural applications.

The test results indicate that beams fabricated from tempered material (-H34 or -T6 tempers) are definitely stronger than beams fabricated from annealed material, all of the beams fabricated from tempered materials having ultimate strengths equal to at least 90% of that of the extruded beams.

There appears to be a great future in the use of the aluminum alloys for structural members.

4. Papers Which Deal with the Development of New Materials That Are Available Now for Welding

My fourth classification is on papers that point out the development of new materails that are available now for welding. The materials I have reference to may be plate, sheets or welding electrodes.

A series of three papers will be given in Session 10 on pressure vessels dealing with special tempered steels for pressure vessel construction. These papers will deal with the tests conducted on 8 welded cylindrical pressure vessels, 20 ft long and 4 ft in diameter, which were refrigerated to subzero temperature and tested to destruction.

A discussion of many laboratory research and development data on the steel prior to the large full-scale testing program will be described.

Tests show that quenched and tempered steel plate is characterized by high yield strength, superior toughness and good weldability, possessing a combination of properties not available before in engineering materials.

This series of papers will also include a special paper on the design factors to be considered in the fabrication of a high-strength quenched and tempered steel vessel. A separate paper on the same subject will deal with the amount of ductility needed for fabrication.

It will discuss, in particular, high elastic ratios, relationship between ductility and toughness, design on yield strength instead of ultimate strength, the need or lack of need for stress relieving, and the philosophy underlying the burst test and the drop tests in Operation "T-1."

The advantages of tempered steels are:

1. High notch toughness at low temperature.
2. High yield strength to ultimate tensile strength ratio.
3. Good weldability.
4. Stress relieving not necessary.

A paper on "Hardenability Evaluation of Welding Electrodes" will be given in Session 11.

The recent trend in high tensile strength, from 200,000 to 300,000 psi,

in fusion deposit weld metal for aircraft application is receiving considerable attention.

This paper will give the results after thermal treatments of the tensile strength of the weld metal and parent stock.

The report covers testing procedures and results of many tests for electrode deposit evaluations after heat treatment. In most cases it is desirable after thermal treatment to have the tensile strength of the weld match that of the parent stock.

It will also include a discussion of a new proposed military specification designed to cover this field of high tensile strength welding.

One of the newer metals that has received a considerable amount of study in regards to its weldability is molybdenum. A paper on "The Flash Welding of Commercial Molybdenum" will be presented in Session 2.

This paper will deal with arc-cast molybdenum in thin sections which is flash welded. The bend ductility of the flash weld depends on the weldments fibering, carbide precipitation, porosity and grain-coarsening of the weld zone, and is therefore critically influenced by platen acceleration, amount of upset, and welding atmosphere.

Under moderate amounts of upset and moderate platen acceleration, welds made in air exhibit acceptable ductility, whereas the ductility of the welds made in argon or hydrogen is always low regardless of the upsetting conditions.

Some very promising new developments have been made in the field of brazing. Of special interest is the paper entitled "Lithium Additions to Brazing Alloys," to be given in Session 13.

The addition of lithium as a strong deoxidizer is useful, not only in the production of gas or porous free brazing alloys, but also it is useful for improving wettability. Small lithium additions, less than 1% by weight, will cause pure silver to wet steel in inert atmospheres.

"Jim" (Kirk) did a fine job in billing an outstanding barn dance troupe. Kansas City will long be remembered for the swell evening that was had by all

Experimental work has proved the possibilities of making self-fluxing brazing alloys of various compositions by adding lithium. Such alloys can be used for brazing in a neutral atmosphere without either flux or reducing gases. These alloys offer much promise in steels with highly refractory oxides, as, for instance, Cr_2O_3 in stainless steels. Lithium modified silver base brazing alloys will torch braze stainless steel in ordinary air without fluxes.

This is a new approach to brazing problems and appears to be promising in the solution to many difficult problems, especially those connected with the brazing of stainless steels and special metals.

It is impossible to adequately give you the highlights of all the papers, but an attempt has been made to stimulate your interest so that this presentation might be a guide as to what you may expect and also what particular sessions you may want to attend.

You can fully appreciate and realize that this year's session is one that is of tremendous interest to all of us in the Welding Industry and I hope that your participation in these sessions, both by discussion and by direct contact with the authors, either verbally or written, will be profitable to you.

The discussion periods, which are alloted at the end of each paper, gives you an opportunity to clear up some of the points which may arise in your minds during the presentations.

All of the papers will be printed in The Welding Journal. Some of these have already been printed, while others will be appearing in the next few issues.

The Meaning of Sustaining Membership in AWS

By J. H. HUMBERSTONE

President, American Welding Society

It is very gratifying indeed to meet with you today. Your presence most emphatically indicates that you are deeply interested in both the present and the future welfare of our American Welding Society. Your very evident interest is likewise gratifying to all of those you have elected to be responsible for handling your Society's affairs. They feel that the future of the Society requires an interested, an informed, a strong and an ever-growing body of Sustaining Members.

I will speak for some twenty to thirty minutes, telling you what can be told about our Society in that brief period—the purpose of this meeting and what you can do to help. And then, what is still more to the point, I hope that you will take the opportunity of expressing yourself—following my address—in the discussion which will follow and which will be moderated by Vice-President C. P. Sander.

This meeting is designed to give greater recognition and more substance to the Sustaining Membership classification. Since a membership of this type costs considerably more, I must conclude that you who are here today, and the companies you represent, must have a very great interest in welding and in the contribution that the AWS

can make in furthering your interests in the welding field. That being the case, the SOCIETY's management would be remiss in not recognizing that fact and so make every attempt to solicit aid to the end that we might better accomplish our objects.

The Executive Committee and Board of Directors are acting on the theory that an annual gathering such as this will provide the opportunity to acquaint you more specifically with our accomplishments and problems. They also feel that such a program will prompt more men and more organizations to participate with you as Sustaining Members, thereby improving our financial position, our magnitude of interest, and so provide greater benefits to members, users, producers and suppliers alike.

We need greater contact with executive talent who represent the consumer, the producer, and the supplier interests. It is essential to know what they want if we are to perform the functions expected of us. Obviously the best way to develop those contacts is through that type of membership which is designed for companies whose *investment* in welding is considerable—companies represented by designated men who recognize and appreciate how instrumental the AMERICAN WELDING SOCIETY is in making that welding *investment* more secure and more valuable.

Where can we find, more readily, the qualities we need than in those places where they are already recognized? We obviously must go to companies where the interest in welding is great and to men in positions of management influence and authority.

We approach you, then, not only because you have the executive talent which is essential to the vigor and growth of an organization, but because you are aware of the size of your company's welding investment and because you—perhaps more than any other single group—are aware of the responsibility you have toward the welding industry in terms of further development and research for continued progress. This awareness carries with it a recognition of the obligation we all have to the AMERICAN WELDING SOCIETY as an industry service organization.

There is a vital relationship, of course, between progress in the Welding Industry and the many activities of the AMERICAN WELDING SOCIETY.

It is, to me, an exhilarating fact that welding has won for itself an indispensable place in American industry as a primary production tool. And it has—by that very fact—won an important place in American life, touching virtually every facet of our existence, from items of a direct defense nature to those which contribute to our immediate comfort, convenience, instruction and entertainment.

Along with the widespread recognition of welding as a process offering unique advantages to industry, there has been a phenomenal increase in the consumption of welding products—a consumption that has been expanding much faster than business activity. This means that the greater utilization of welding is related not only to general economic conditions conducive to growth in *any* field, but that developments within the welding field itself have stimulated the expansion rate in excess of the over-all production rate increase.

The largest single factor in the cost of production, as we all know, lies in labor. The great progress of machine welding of high production items—which cuts labor costs to a minimum—reflects the accomplishment of research that has enabled industry to put new welding techniques to work on the assembly lines of the nation. The net result is a higher usage rate for welding products per unit of factory output. It also means larger profits for those who produce and a lower selling price to those who buy.

I talk in terms of production, costs and sales as a typical business man should. But we must recognize that members of the AMERICAN WELDING SOCIETY often enter areas of activity removed from immediate or special concerns with production, costs, sales. Nevertheless, AWS activities lie at the very root of the increasing sale—and use—of welding products and supplies.

It is imperative that we concern ourselves with more than the *immediate* interests—the short-term objectives—good and sound as they may be, of the companies we work for. The AWS provides the basic philosophy, the mechanics, and the organization essential for this type of activity.

The AWS operates and accomplishes much on a surprisingly small income. For example, the budget last year was $390,000, both on the income and the expenditure sides. Ninety-nine percent of this figure was spent on activities of benefit to the SOCIETY members and industry. Only 41 percent of the SOCIETY's total income was derived from membership dues. The balance, or 59 percent of its total income, was actually earned by the SOCIETY.

What are some of the things we would do with more money from a larger membership? There are urgent needs for additional work on codes, specifications and standards. Not only are there new processes and new applications coming into being that require attention by our technical committees, but certainly with the great increase in the number and magnitude of applications—and the universal acceptance of the welded joint—we know that there is ample op-

We are not quite sure how it came about, but we understand that "Si" Greenberg, AWS Technical Secretary, posed a technical question to someone. Rightfully, he was judged and sentenced to the stocks

portunity for simplification of existing codes, specifications and standards.

Last year the SOCIETY contributed approximately 11% of its expenditures to providing the technical services which produce the codes, standards and specifications for the industry. With more income the SOCIETY will accomplish more of this essential work.

At this point it might be of interest to you to know what happens to the other 89% of the SOCIETY's income. Twenty-six percent of its income is required for maintaining the various direct services of membership; 36% goes for the cost of producing THE WELDING JOURNAL, including the securing and production of advertising, reprints and the administration. The SOCIETY's national meetings and Exposition account for 19% of its expenditures. Under its present ruling, AWS is allowed to set aside only 1% of its annual income in reserve funds, and the SOCIETY is authorized to hold these funds in cash and/or investments approved by the State of New York for fiduciaries as permitted by Section 21 of the Personal Property Law of the State of New York. Two percent is spent for the WELDING HANDBOOK and 1% for educational books. The remaining 4% is spent for miscellaneous activities and items such as supplies and equipment.

Technical activities that assist the welding industry can be materially increased. Work with local and national governmental agencies needs to be carried on so that welding might have further promotion and not suffer from legal restrictions. Work with universities needs to be fostered and this includes

AWS BUDGET (1954)

Income ($390,000) from—	
Membership dues	41%
JOURNAL advertising, Research Supplement, Sale of Reprints, and Subscriptions*	33%
National Meetings and Exposition	17%
Sale of Technical Codes, Standards, Specifications	2%
Sale of Handbooks	3%
Educational books	2%
Miscellaneous	2%
	100%
Expenditures ($390,000) for—	
Membership service cost	26%
JOURNAL printing, advertising, reprints, administration	36%
National Meetings and Exposition	19%
Production of Technical Codes, Standards, Specifications	11%
Handbook and service cost	2%
Educational books	1%
Miscellaneous activities, supplies and equipment	4%
Reserve Funds	1%
	100%

* In addition, a portion of Dues from Membership is allocated to THE WELDING JOURNAL.

text and reference books for classroom and business organizations alike.

Educational activities mean that we need to stimulate a greater interest in welding on the part of engineering schools—yes, even in high schools, For we can all agree that industry needs young men with a working knowledge of welding, not just a casual acquaintance with it, since all industry uses welding today.

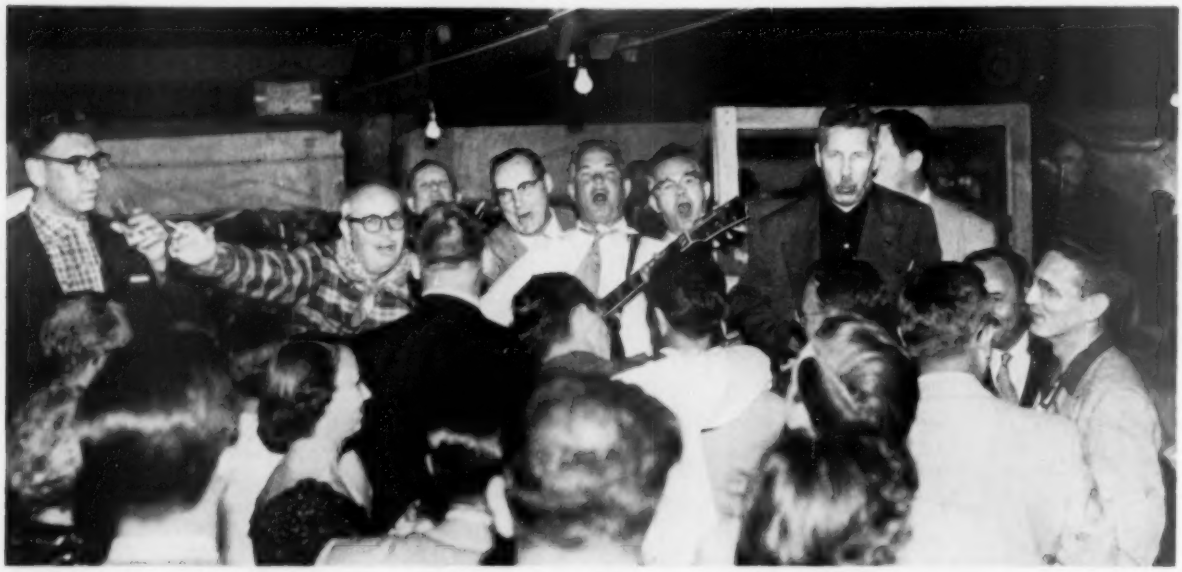
In connection with reference books, it is imperative that I mention our need for a new edition of the WELDING HANDBOOK. This in itself represents a major task and constitutes a substantial financial burden.

We are now trying to find ways and means of accomplishing this objective. As a matter of fact, it represents one of my prime objectives during my term in office. By that I do not mean that the new edition can be put in your hands during my term, but I certainly expect to see this project well under way.

Need I say that all of this program will require not only money but a lot of manpower? That is obvious and you can help on both counts. Unless we do obtain ample participation of technical personnel and ample financial support, these desired accomplishments will lag as they have been lagging for some time because we are hard-pressed to keep up.

With the wonderful cooperation of the membership, which now numbers 10,500 the SOCIETY has had an extraordinary expansion in its activities. Unlike most technical societies, it is an adjunct to industry in that its membership comprises a broad occupational range in each industry.

What is most interesting is that 5% of our SOCIETY's membership (approximately 530) comprises company corporate officers, starting at the top with the President or Chairman of the Board. This is an extremely high percentage and it is not found in societies other than those devoted almost entirely to managerial problems—which is not so in



What "Jim" (Kirk) didn't figure on was that some of the out-of-towners aspired to "out amateur" the professionals! "Bill" Lilly is swinging a wide open "Caroline," while Secretary "Joe" Magrath is trying to whistle, hog-call, or give a Bronx cheer (we can't figure which), and President "Joe" (Humberstone) seems to look on with astonishment and wonder as to how he ever got involved in such a deal!

And so, toward the end, where we find Past-President "Fred" Plummer and "guess who" group sadly quartetting "Show me the way to go home; I'm tired and wanta go to bed!" It was a fine convention, with lots doing—good business and good fun. We wish you all had been there!

the ordinary technical society. It indicates that welding is such an important operation in industry that it comes to the attention of industry executives and they feel they should be very closely and currently informed in regard to the latest developments in, and information on, welding and welding engineering.

The broad range of membership—which includes engineers in every category, shop supervisors, metallurgists, physicists, educators, shop owners, contractors, sales promotion and advertising men, and welders who work for wages—is further certification of the interest welding holds for those in various occupations and its importance to the fabricator. Knowledge of welding procedure and design is required throughout the entire range of a fabricator's organizational structure.

AWS Membership (10,500 Basis)

28%	Engineers (72 classifications)	2,940
27–28%	Supervisors to Superintendents	2,890
13%	Metallurgists, Physicists, Educators	1,360
7–8%	Welding Shop Owners, Contractors	785
7%	Welders (work for Wages)	735
7%	Sales Promotion, Advertising, etc.	735
5%	Top Management (Corporate Officers)	530
3%	Miscellaneous Professions and Occupations	315
2%	Draftsmen and Designers	210
100%		10,500

A membership of this range and quality provides an unexcelled manpower tool for committee work. Certainly we are making every attempt to utilize that manpower, for today there are more than 100 technical and administrative committees and subcommittees performing valuable work which contributes substantially to the growth of our industry.

On the basis of trends established by current performance, 1955 will go into the records as one of the best years in the history of the welding industry. As a matter of fact, we expect it to be better than 1954 when industry consumed more than half a billion dollars worth of equipment and supplies related to welding, cutting and allied processes.

Over the years, the National Meetings of the Society, plus local Section Meetings, the monthly issues of The Welding Journal, and now two great annual conventions, have established the value of a technical forum of major magnitude—a kind of industrial seminar for contributions to the sum of engineering knowledge: Progress reports, new developments in the field and differences of opinion.

Thinking of this as supplementing the major contributions made by the men of industry both in the consuming and producing fields, the research engineer, the application engineer—those who were willing to invest capital in the new approach—we can then appreciate how a more exact knowledge and improved welding practices have continually emerged, laying the basis for the kind of progress and prosperity we are now enjoying and will continue to enjoy.

I want to comment more specifically on the relationship between AWS committee work and progress in the welding industry. Examples are many, but two or three will suffice to illustrate this relationship and underscore its importance.

For some 20 years there has been a need, repeatedly asserted, on the part of users and fabricators alike, for an improved ordinary carbon steel material that would be more appropriate for welding. Intensive studies have culminated in the issuing of two such specifications of the American Society for Testing Materials: (1) structural steel for ships, and (2) structural steel for welding.

Particularly in the case of structural steel for welding, representatives of technical committees of the AWS were called upon to perform, in cooperation with steel mill metallurgists, the major role in working out acceptable provisions.

The Filler Metal Committee has continued to be very active, having turned out revisions to existing codes and specifications along with certain new ones. A few of the more important revisions are:

(*a*) The revision to the specification covering mild steel electrodes, including coverage of the iron powder types now known as E6024 and E6027.

(*b*) A revision of the low-alloy steel electrode specification. This specification will certainly

prove to be more useful since attention is finally being given to the chemistry of the deposited metal, each classification providing for various analyses.

(*c*) Revisions to the stainless steel specification wherein many additional types were added.

(*d*) A new specification covering nickel electrodes.

(*e*) A new specification on tungsten electrodes.

(*f*) And a broad series of specifications covering bare wires in coiled form for the inert-arc processes.

In addition, other specifications are in the process of revision, such as those for brazing filler metals.

Under preparation are others which will cover filler metals for cast iron welding, and nickel filler metals for the inert-gas processes.

Another accomplishment of major magnitude is the production of a long-needed Brazing Manual by the AWS Brazing Committee. Even though brazing is one of our oldest fabrication processes, this is the first time that a work of this nature has been compiled. This manual will be published in the form of a bound, hard-cover volume containing about 200 pages and will be available in July. The same committee is now preparing a similar work dealing in soldering.

There are important parallel activities in our sister organization, the Welding Research Council, upon which I shall not dwell, except to say that various committees of that organization—which treat with fundamental and specific research problems—develop information which provides the necessary basis for further progress in some of the technical committees of the AMERICAN WELDING SOCIETY.

Now I would like to be more specific about the stated objects of the Society. This subject is timely in view of the fact that we are in the process of incorporating into our Constitution a modern version of those objects which have stood so well over the past many years. A new statement has been drafted which better states our objectives and which I shall quote:

THE OBJECTS OF THE AMERICAN WELDING SOCIETY SHALL BE:

To encourage in the broadest and most liberal sense the advancement of welding;

To encourage and to conduct research, both basic and applied, in all sciences as they relate to welding;

To improve the education and usefulness of personnel engaged in and associated with welding activities;

To engage in and assist others in the development of sound practices for the application of welding and related processes;

To disseminate welding knowledge through its publications, meetings, discussions, consultations, exhibits and by any other available means; thereby fostering public welfare and education, aiding in the development of our country's industries and adding to the material prosperity and well-being of our people.

To sustain these laudable objects—and to help translate them into actual accomplishments—Sustaining Memberships are essential. In many instances it is not so much a matter of membership but of the extent of membership and of participation. This extent of membership is, in a large number of companies, very low in relation to the company investments in welding and the benefits derived from AWS promotion of welding.

As I stated earlier, the AWS invests 99% of its income toward the promotion of the general cause in welding. Your membership dollar is an investment in welding. How small—yet how important—is the $150 Minimum Sustaining Membership Fee in relation to the size of your company's welding investment—plant, equipment, manpower, engineering, quality product and reputation—and the benefits you and your company derive from AWS activities.

There are thousands of products today made of metal fabrication which could not be produced were it not for welding and the work done by the AWS and those who have supported its activities. There are hundreds of manufacturers who would not be in a competitive position were it not for the information made available to them through the AWS. There are many companies who would not be in business were it not for welding having made it possible for them to manufacture the product they produce and sell.

From purely the standpoint of "production and investment," industry should recognize that it has a tremendous wage investment in welding labor and capital investment in welding equipment.

A small fabricator will have from $50,000 to $100,000 capital investment in welding equipment, and $100,000 to $200,000 annual investment in labor and supervision directly connected with welding. A large fabricator may have as high as a five million dollar annual labor investment and a two to three million dollar capital investment in welding equipment.

Surely it follows that anything that can be done toward increasing the values of these investments is worth while. That being the case, increasing the knowledge of personnel relative to welding procedures, processes and available equipment can only result in more intelligent application and supervision and greater productivity. The return is many, many times the small cost involved in AWS membership which, after all, is a vehicle for providing a post-graduate course in welding engineering and welding design.

At this point I am confident that I have succeeded in selling you on the importance of the Sustaining Member, on the importance of the WELDING SOCIETY, on the need for an ever-growing and active body of Sustaining Members.

You can perform, as a member of the management of this SOCIETY, the service of spreading the word and selling others—other executives and other organizations—on the importance of supporting the work of this SOCIETY by participating as a Sustaining Member.

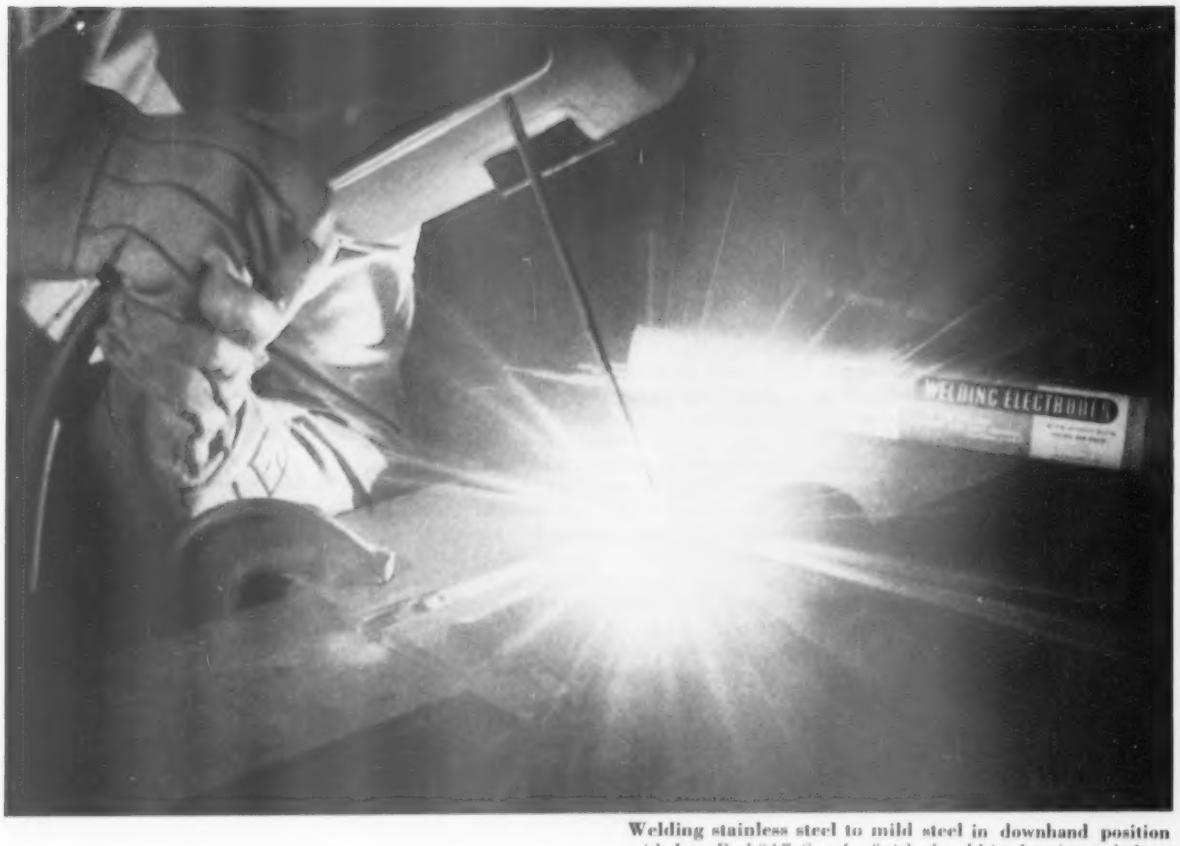
I do not believe that anyone can do that job better than a Sustaining Member. In your business establishments you do not send a boy to do a man's job. That being the case, who better than a participating company executive can sell other executives having comparable responsibilities and interests on the idea of supporting our SOCIETY through Sustaining Membership?

I have participated in the management of this SOCIETY long enough to know that the management of the past several years has been trying to do what is best for industry and what is best for the future of welding.

In reviewing the Sustaining Membership list and realizing the extent to which the companies represented thereon support the AWS in other membership classifications—as well as realizing the money they spend in permitting their people to participate not only in our technical affairs but in others—I can only come to the conclusion that this SOCIETY—to a considerable extent—is in your hands—you support it. Therefore, if it is not accomplishing what you want it to accomplish, it is in your power to change it. You can help through constructive criticism and suggestions. You can do this at any time by attending Board Meetings, Executive Committee meetings, Technical Council meetings, or by letter to any of the officers.

It stands to reason that those who participate most will benefit most. But I want to stress that, regardless of the extent of membership and participation, companies concerned with welding and affected by it will continue to derive benefits from AWS activity.

In a way the matter becomes a point of personal grace, of practical enlightenment to see, and feel, this obligation. The act of joining is an outward token of this inner grace.



Welding stainless steel to mild steel in downhand position with Inco-Rod "A". See the finished weld in the picture below.

For welding dissimilar alloys ...NEW INCO-ROD "A"

You'll like the versatility of the new Inco-Rod "A"...

It welds many combinations among such dissimilar alloys as ferritic and austenitic stainless steels, mild steels, low alloy steels, and high-nickel alloys.

Inco-Rod "A" is expected to give sound, strong and ductile welds on better than 90 per cent of dissimilar metal jobs in the average plant.

Extensive tests, in both field and laboratory, indicate that most joints involving dissimilar alloys can be welded with Inco-Rod "A".

* * *

Get the free new booklet on Inco-Rod "A". It tells you where to use Inco-Rod "A". It gives you data on test-welds of 21 different alloy combinations—facts about the excellent tensile and bend properties obtained. Write Inco today for this helpful booklet.

Six more reasons you'll like new Inco-Rod "A":

1. **Ease of welding** — Inco-Rod "A" has excellent operability in all positions — with spray-type arc and good slag removal.
2. **Dependability** — Inco-Rod "A" permits production of X-ray quality welds.
3. **High corrosion resistance** — Inco-Rod "A" produces welds with corrosion resistance expected to equal or exceed, in most cases, that of either alloy being welded.
4. **Handy packages** — Inco-Rod "A" comes in 5-lb., asphalt-lined, protective tubular containers.
5. **Four convenient sizes** — Inco-Rod "A" is supplied in 14-inch lengths in four diameters: 3/32- with center grip and 1/8-, 5/32-, and 3/16-inch with end grip.
6. **Distinctive flux color** — The green flux coating of Inco-Rod "A" prevents mix-ups with other electrodes.

Note close ripples and even contour of weld made with Inco-Rod "A". This versatile electrode was developed specifically for joining dissimilar metals to each other.

THE INTERNATIONAL NICKEL COMPANY, INC.
67 Wall Street New York 5, N. Y.

INCO
TRADE MARK

Welding Products
Electrodes • Wires • Fluxes

TAC TALKS

Welding Symbols

by H. Malcolm Priest

The Committee on Symbols is one of the oldest committees of the AMERICAN WELDING SOCIETY. It had its inception when an urgent need for welding symbols arose in the preparation of drawings for the first welded structures. From a simple beginning in the days when arc and gas welding with bare wire were the only welding processes used, the symbols have kept pace with the increasing demands of a rapidly expanding welding industry.

Because of the all-inclusive nature of the symbols, the Committee has always worked closely with other technical committees of the SOCIETY, among them being the Committee on Definitions and Chart, and those which have to do with welding processes. This collaboration has undoubtedly contributed to the elimination of confusion and to the progress of welding.

After many meetings of the Committee, a thorough revision and expansion of the symbols was published in 1947. So complete and comprehensive was this revision that not until recently have there been any requests for additions.

During the past year, the aircraft industry submitted suggestions for additional symbols to meet a need brought about by the extensive use of thin metal construction in aircraft structures. The Committee has already held three meetings to consider these suggestions and to establish new symbols to cover the type of flange joints which are common in that field. In so doing, the Committee has been mindful of possible uses of the new symbols in other fields and, as always, has endeavored to suit them to universal application.

The welding symbols of the AMERICAN WELDING SOCIETY have been widely accepted throughout industry and incorporated in the specifications of governmental agencies, such as those of the Army and Navy. The symbols adopted by the Institute of Welding in Great Britain are the same with very minor exceptions. The American Standards Association adopted our symbols and has long included them in their growing list of standards. Thus, the authoritative position of the AMERICAN WELDING SOCIETY with respect to symbols is well recognized.

Functioning under the general supervision of the Technical Activities Committee of the SOCIETY, the Committee on Symbols has had for its goal the simplification of the work of drafting rooms and fabricating shops in the Welding Industry, by developing a clear and unmistakable language of symbols. We believe the Committee has been successful in achieving this goal.

H. Malcolm Priest is Chairman, AWS Committee on Symbols, and Manager, Railroad Research Bureau, United States Steel Corp.

New Sustaining Member

Arcos Corp., 1500 S. 50th St., Philadelphia 43, Pa., produces a line of filler metals for welding stainless, low alloys, nonferrous metals and aluminum. Its products consist of coated and bare electrodes and rods in cut, spooled or coiled form suitable for manual arc, inert gas or submerged arc welding. For root pass welding of pipe, Arcos produces the EB Weld Insert which permits welding from one side without any back-up device. For cutting tough metals, including all kinds of alloys and cast iron, Arcos offers the Oxyarc process.

Sustaining Member Representative is R. D. Thomas, Sr.

FOR YOUR INFORMATION

Here are some new AWS standards you may have missed—

	Price per copy
* Mild Steel Arc-Welding Electrodes, Specifications for	40 cents
Nickel and Nickel-Base Alloy Covered Electrodes, Specifications for	40 cents
Aluminum and Aluminum-Alloy Welding Rods and Bare Electrodes, Specifications for	40 cents
Corrosion-Resisting Chromium and Chromium-Nickel Steel Welding Rods and Bare Electrodes, Specifications for	40 cents
Application of Metallized Coatings to Protect Against Heat Corrosion; Part IC of Recommended Practices for Metallizing	50 cents
Safe Practices for Inert-Gas Metal-Arc Welding	50 cents
Repair Welding of Cast Iron Pipe, Valves and Fittings, Recommended Practices	50 cents
Postweld Heat Treatment of Austenitic Steel Weldments, Recommended Practices	50 cents
Copper and Copper-Alloy Electrodes, Revised Specifications	40 cents
Spot Welding Aluminum and Aluminum Alloys, Recommended Practices	$1.00

* Includes Iron Powder Electrodes

Send your order for any of these publications or your request for more information to AMERICAN WELDING SOCIETY, 33 W. 39th St., New York 18, N. Y.

TECHNICAL PAPERS SESSIONS

1955 NATIONAL FALL MEETING

OCTOBER 17-21 • BELLEVUE-STRATFORD HOTEL, PHILADELPHIA, PA.

OCTOBER 17, MONDAY AFTERNOON

Three Simultaneous Sessions

1. CO_2 GAS SHIELDED WELDING

A. Carbon-Dioxide Shielded-Metal Arc-Welding Process
by Robert J. Keller and John P. Koss, A. O. Smith Corp.

B. Moisture and Its Effects in Carbon Dioxide Welding of Steel
by Roger W. Tuthill, General Electric Co.

C. Electrode Characteristics for Welding Mild Steel in Atmospheres of Carbon Dioxide by the Consumable-Electrode Gas-Shielded Welding Process
by Robert D. Mann and Julian D. Carey, General Electric Co.

2. RESISTANCE WELDING

A. The Behavior of Spot-Weld Cross-Section During Loading
by John F. Rudy, Wright Air Development Center, Roy B. McCauley and Robert S. Green, Ohio State University

B. Seam Welding Dissimilar Thicknesses of Low-Carbon Steel
by M. L. Begeman and Ernest J. Funk, University of Texas

C. Resistance Spot-Welding Schedules for Welding Projection Hardware to Mild Steel Sheet and Plate
by O. K. Barnes, Westinghouse Electric Corp.

3. WELDABILITY AND RESEARCH

A. Effect of Preheating on Stress-Corrosion Cracking of Steel Weldments
by E. Paul DeGarmo and I. Cornet, University of California

B. Heat Treatment of Air Hardening Alloys on Welding
by John J. B. Rutherford and John F. Ewing, Babcock & Wilcox Co.

C. The Development of High-Tensile High-Impact Electrodes
by G. S. Wepfer, A. O. Smith Corp.

OCTOBER 18, TUESDAY MORNING

Three Simultaneous Sessions

4. WELDABILITY AND RESEARCH

A. Further Studies of the Hot Ductility of High-Temperature Alloys
by Ernest F. Nippes and Warren F. Savage, Rensselaer Polytechnic Institute

B. Influence of Lattice Structure Upon Strength Ductility-Temperature Relationships
by Julius Heuschkel, Westinghouse Electric Corp.

C. A Welding Test for Gray and Nodular Cast Iron
by A. L. Schaeffler and W. A. Schumbacker, Allis-Chalmers Manufacturing Co.

5. STRUCTURES

A. Fatigue Strength of Welds in Low-Alloy Structural Steels
by G. E. Nordmark, W. H. Munse, J. E. Stallmeyer and N. M. Newmark, University of Illinois

B. Welding of Structural Steel for Hartford Library
by Carl L. Kreidler, Lehigh Structural Steel Co.

C. Fabrication of Crosshead Beams for the World's Largest Hydraulic Press
by V. M. Nigriny, The Midvale Co.

6. INSPECTION AND TESTING

A. Backing Ring Elimination Permits Ultrasonic Testing and Avoids Cracking of Piping Welds
by Wilfred A. Pollock, Wisconsin Electric Power Co.

B. The Gamma Radiographic Control of Welded Transmission Pipe Lines
by Colin M. C. Bales, Welding Supervision Ltd.

C. Radiography in the Jungles of Sumatra, Indonesia
by Walter W. Offner, X-ray Engineering Co.

OCTOBER 18, TUESDAY AFTERNOON

Three Simultaneous Sessions

7. WELDABILITY AND RESEARCH

A. The Effect of Microstructure on Notch Toughness and Fracture Morphology—Part II
by Joseph C. Danko, John H. Gross and Robert D. Stout, Lehigh University

B. Crack Arresting by Overlays of Notch Tough Weld Metal
by P. P. Puzak and W. S. Pellini, Naval Research Laboratory

C. Studies on the Brittle Failure of Tankage Steel Plates
by M. S. Northup, F. J. Feely, Jr., and S. R. Kleppe, Esso Research & Eng. Co., Max Gensamer, Columbia University

8. SHIPBUILDING

A. Offshore Drilling Barges
by Robert H. Macy, The Ingalls Shipbuilding Corp.

B. Building an All-Welded 96-Ft Twin-Screw Yacht
by LaMotte Grover, Air Reduction Co., and E. H. Holder, Ingalls Shipbuilding Corp.

C. Stress Studies of Various Shaped Welded Doublers in Hatch Corner
by Yoshio Akita, Transportation Technical Research Institute of Japan, H. Kihara, University of Tokyo, N. Ando, Transport Technical Research Institute and K. Yoshimoto, Ishikawajima Heavy Industry Co.

9. WELDING EQUIPMENT

A. Characteristics of a Rectifier Type Constant Voltage Power Supply
by Jesse W. Pomazal, Harnischfeger Corp.

B. Transient Problems When Using Hypersil Transformers in Welding Applications
by Robert C. Mierendorf, Square D Co.

C. Power Sources for Inert-Gas-Shielded Consumable Electrode Welding
by A. Lesnewich and Everett Cushman, Air Reduction Co., Inc.

OCTOBER 19, WEDNESDAY MORNING

Three Simultaneous Sessions

10. STAINLESS STEELS

A. Mechanical Properties of Modified Type 347 Weld Deposits
by Lorin K. Poole and R. David Thomas, Jr., Arcos Corp.

B. Hot Cracking of Stainless Steel Weldments
by P. P. Puzak W. R. Apblett and W. S. Pellini, Naval Research Laboratory

C. Permeability and Crack Sensitivity of Stainless Welds
by John L. Lang and Charles Wright, Jr., Lukens Steel Co.

11. WELDING ELECTRODES

A. Metal Powder Electrodes and Their Applications
by E. DiLiberti, Air Reduction Sales Co.

B. Properties and Applications of Low-Hydrogen Iron Powder Electrodes
by D. C. Smith, W. G. Rinehart and D. C. Helton, Harnischfeger Corp.

C. Effect of Individual Coating Ingredients on Surface Tension of Iron Electrodes
by Thomas H. Hazlett and Earl R. Parker, University of California

12. APPLICATIONS

A. Selection of Proper Inert-Gas-Shielded Arc-Welding Process
by J. Warden Cunningham and Harry A. Huff, Jr., Air Reduction Sales Co.

B. High-Speed Welding of Steel Compressor Cases
by C. F. Stephenson, York Gruntly Division of York Corp., and Robert A. Stone, Air Reduction Sales Co.

C. New Surfacing Techniques
by K. H. Koopman and R. S. Zuchowski, Linde Air Products Co.

OCTOBER 19, WEDNESDAY AFTERNOON

Three Simultaneous Sessions

13. TITANIUM & MOLYBDENUM

A. Welding of Titanium
by E. F. Gorman, Linde Air Products Co.

B. Resistance Welding Ductile Joints in Commercially Pure Titanium
by Robert Wickham, Marquardt Aircraft Co.

C. Effects of Oxygen on Soundness and Ductility of Molybdenum Welds
by W. N. Platte, Westinghouse Electric Corp.

14. WELDING ELECTRODES

A. A New Approach to Welding of Alloy Steels with Alloy Fluxes
by Emmett Smith and Paul Jerabek, The Lincoln Electric Co.

B. The Effect of Aluminum Additions to Mild Steel Weld Metal
by Craig R. Sibley, Air Reduction Co., Inc.

C. Effect of Current and Atmospheres on Arc Temperatures
by George M. Gordon, Olga A. Cotter and Earl R. Parker, University of California

15. PRESSURE VESSELS

A. Performance of High-Strength Pressure Vessel Steels
by J. H. Gross and R. D. Stout, Lehigh University

B. Resistance of Low-Alloy Steel Plates to Biaxial Fatigue
by C. E. Bowman and T. J. Dolan, University of Illinois

C. The Practical Approach to the Welding of Stainless Steel Pressure Vessels
by Frederick H. Clash, Jr., Link-Belt Co.

OCTOBER 20, THURSDAY MORNING

Three Simultaneous Sessions

16. ALUMINUM

A. Inert Shielding Gases for Welding Aluminum
by James D. Dowd, Aluminum Company of America

B. Hydrogen vs. Acetylene vs. Inert Gas in Welding Aluminum Alloys
by J. Koziarski, Piasecki Helicopter Corp.

C. Welding Aluminum to Copper Using Inert-Gas Metal-Arc Process
by L. A. Cook and M. F. Stavish, Kaiser Aluminum & Chemical Corp.

17. PIPING & PRESSURE VESSELS

A. Welding of High-Temperature High-Pressure Piping with Chrome-Moly Electrodes
by Loyd D. Nesbitt, Metal & Thermit Corp.

B. The Application of Inert-Gas Tungsten-Arc Welding to Carbon Steel Pipe
by F. J. Pilia and R. W. Minga, Linde Air Products Co.

C. Welding of Pressure Vessels with Automatic Submerged Arc
by Wilmer W. Weber, The Pfaudler Co.

18. APPLICATIONS

A. Automation of Metal Manufacturing Requires Correct Use of Arc Welding
by H. O. Klinke, The Taylor-Winfield Corp.

B. How to Apply Automatic Submerged Arc Welding
by Robert Wilson, The Lincoln Electric Co.

C. Lower Part Cost by Projection Welding
by C. H. Burgdon, Deere & Co.

OCTOBER 21, FRIDAY MORNING

Three Simultaneous Sessions

19. BRAZING

A. Wettability of Steel with Pure Silver and Silver Brazing Alloys
by Nikolajs Bredzs, Armour Research Foundation of Illinois Institute of Technology

B. Physical Properties of Butt Joints Brazed with BCu, BAg-1, and BAg-3 Filler Metals
by Grant Hansel, Jr., Materials & Processes Laboratory, General Electric Co.

C. Automatic Blade of High Solidity Axial Flow Fans
by John B. Hill, Jr., Sawyer-Bailey Corp.

20. MAINTENANCE & PRODUCTION

A. Effective Welding Circuit Maintenance
by Donald L. Caldwell, Caterpillar Tractor Co.

B. Production Methods for the Fabrication of Rear Axle Housings
by E. Lommel, Chevrolet Division, General Motors Corp.

C. Contour Beveling with the Electronic Tracer
by Howard B. Cary, Marion Power Shovel Co., and R. F. Helmkamp, Air Reduction Sales Co.

21. APPLICATIONS

A. How to Use Steel Effectively in Machinery
by Omer Blodgett, The Lincoln Electric Co.

B. An Application of the Pressure Welding Process to Fabricate Continuous Rail
by D. C. Hastings, Richmond, Fredericksburg and Potomac Railroad Co.

C. Manual Arc Welding of Butt Joints in Crane Rails
by Ivan Kutuchief, A. O. Smith Corp.

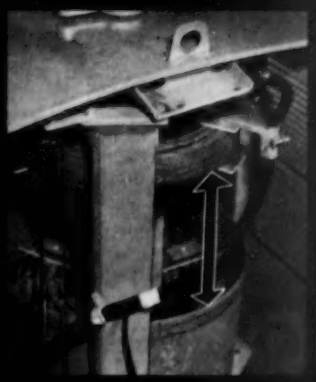
The above schedule of technical papers is not necessarily final. A more complete and detailed program, including an account of other activities, will be published in the October issue of The Welding Journal.

NEW G-E AC

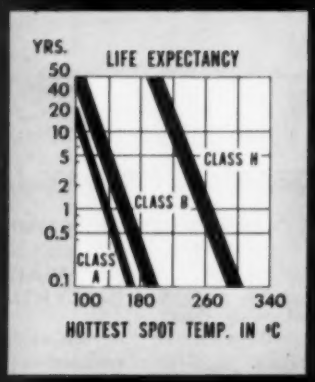
offer a group of tested performance features

COMPARE THE VALUE

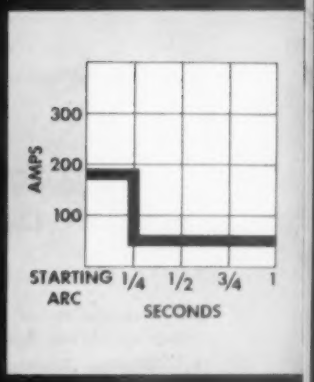
Prove the superiority of General Electric a-c welders to yourself. Just check this feature-by-feature comparison of G-E welders with four other popular makes. You'll see that only G-E provides you with *all* these features . . . for top performance over a long lifetime of service.



MOVING COIL DESIGN: inherent stepless adjustment permits pinpoint accuracy in current settings.



SILICONE INSULATION (Class H) withstands temperature extremes which disintegrate ordinary insulation.



AUTOMATIC HOT START gives instant arc striking throughout current range.

GENERAL ELECTRIC	✓	✓	✓
MANUFACTURER "A"			✓
MANUFACTURER "B"	✓		
MANUFACTURER "C"			✓
MANUFACTURER "D"			

ASK ABOUT FREE TRIAL OFFER—Contact your local G-E Welding Distributor for full information. He is listed in the yellow pages of your phone book. Write for Bulletin GEA-6243 to Sect. 711-2, General Electric Co., Schenectady, N. Y.

WELDERS

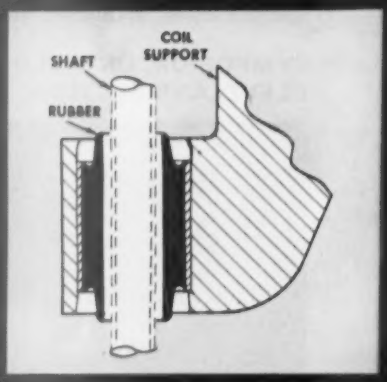
unmatched by any other welder

Four husky ratings—295, 300, 400, and 500 amps; feature high open-circuit voltage.

ARC STABILIZERS assure steady arc, faster welding, fewer "patch ups."

LARGE CURRENT SCALE can be read easily from the job; expanded in low range for extra-fine accuracy.

EASILY REMOVABLE SIDE COVERS: only three screws have to be removed for quick access to inside.



FLOATING-COIL MOUNT eases current adjustment, minimizes friction, noise, wear and vibration.

✓	✓	✓	✓
✓			
	✓		

GENERAL ELECTRIC

Section News and Events

as reported to Catherine O'Leary

SIXTEENTH ANNUAL WELDING SYMPOSIUM

Cleveland, Ohio—A record crowd of over 600 members and guests attended the 16th annual Welding Symposium held recently by the *Cleveland* Section. They heard three technical papers on cost reduction in welding production given by authorities in their respective fields. These included Harry J. Bichsel, Westinghouse Electric Corp.; R. W. Tuthill [AWS], General Electric Co., and Thomas L. Dempsey [AWS], Lincoln Electric Co.

Another outstanding and successful feature of the Symposium were education exhibits sponsored by 18 manufacturers, distributors and users of welding to introduce the latest in techniques, equipment and accessories. The exhibit of Crescent Metal Products, which featured inert arc and resistance welding of aluminum, was named outstanding. Herb Hinkel [AWS], General Electric representative in Cleveland was in charge.

The Symposium was dedicated to Fred L. Plummer, past-chairman of the Cleveland Section, for his outstanding service to the Section and to the welding industry. Mr. Plummer was Cleveland Section chairman in 1940 when the first Symposium was held. He was presented with a desk set by outgoing Cleveland Section Chairman J. Robert Henry, Cleveland Diesel Division, General Motors Corp.

Also featured was the presentation of the Meritorious Service Award to Charles Berka [AWS], associate editor of Industry and Welding, for his contribution in editing Cleveland Section's Monthly Bulletin and Symposium Directory.

Allan P. Stern, president of Colonial Iron Works Co., Cleveland, succeeded Mr. Henry as chairman for 1955–56.

SYMPOSIUM ON WELDING COST REDUCTION HELD BY CLEVELAND SECTION

Educational exhibits featured displays of 18 manufacturers, distributors and users of welding equipment and accessories. Here's part of large crowd on hand

Judged most educational of all exhibits was that of Crescent Metal Products Co. Inert arc and resistance welding of aluminum and magnesium were featured

Charles P. Berka receives Meritorious Service Award for editing Cleveland Section's Monthly Bulletin and Symposium Directory from Chairman Henry

J. Robert Henry, outgoing Cleveland Section chairman (*right*), turns over the gavel of office to his successor, Allan P. Stern

ANNUAL DINNER DANCE

Appleton, Wis.—The First Annual Dinner Dance of the *Fox Valley* Section was held Saturday, May 21st, at the Elks Club in Appleton.

A cocktail hour and music preceded the dinner which was attended by some 135 members, their wives and guests.

The officers and members of the Executive Board were introduced by the outgoing chairman, W. Hart, who reviewed briefly the first year of the Fox Valley Section and its plans for the future.

•

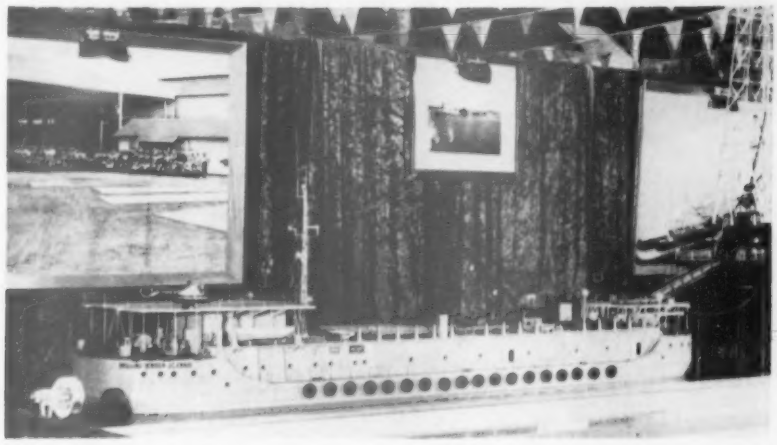
The Fox Valley Section held its annual election with the following results:

Chairman—A. C. Mulder
1st Vice-Chairman—H. Skatrud
2nd Vice-Chairman—J. Revelt
Member Executive Board—R. C. Sommerfeld
Member Executive Board—E. L. Hart

The chairman and vice-chairman were elected for one year terms; the executive board members for two years.

OFFSHORE DRILLING IS SUBJECT AT MEETING OF SABINE DIVISION OF HOUSTON SECTION

Otho H. Haunschild, the principal speaker at the last meeting of the Sabine Division of the Houston Section



Mr. Haunschild's subject dealt with the offshore drilling operations in Gulf of Mexico. Shown above is a model of an offshore drilling tender built by Levingston Shipbuilding Co.

OFFSHORE DRILLING OPERATIONS

Orange, Tex.—Otho Haunschild AWS, yard superintendent of Levingston Shipbuilding Co., recently addressed the Sabine Division of the *Houston* Section at its regular monthly meeting held at Little Mexico Cafe in Orange. Mr. Haunschild presented an outstanding talk on the offshore drilling operations in the Gulf of Mexico and discussed the various types of methods used in the search for oil. He also discussed the welding procedure used in the construction of an offshore drilling tender as built by Levingston Shipbuilding Co. To highlight his talk, he had on display a scale model, 1/2 in. to the foot, of an offshore drilling tender complete to the smallest detail which is a replica of the first non-self propelled offshore drilling tender to be built in the state of Texas. This was the J. C. Craig named in honor of the production superintendent of the Continental Oil Co. and delivered by Levingston to the joint venture known as the CATC Group.

The model is one of the most authentic appearing models constructed to date, showing the operations of an offshore drilling tender adjacent to its drilling platform. The complete exhibit was constructed by the personnel of Levingston Shipbuilding Co. The model measures 10 ft 8 in. long, 2 ft 3 in. wide and 7 in. molded depth at the sides. It is in simulated drilling operations in mooring position and is joined to a scale model of a drilling platform 4 ft 5 in. long, 2 ft 2 in. wide and 2 ft 6 in. high. Upon the platform is mounted a 1/2 in. to the foot scale oilwell derrick, measuring 7 ft 4 in. tall, complete with crown block, traveling block, swivel and kelly joint. One of the outstanding features of this section is the rotary which is in operation. The drilling platform contains the drawworks, operating shale shaker, mud pit, and is completely illuminated. The drilling tender model is complete in detail with the actual vessel including the pipe rack, loaded with drill stem, casing, oil drums and the helicopter landing deck with a model helicopter in position with rotor blades in action.

The authenticity of this model is a tribute to the men of Levingston whose skill and experience, combined with engineering know-how, have earned and maintained for the Levingston Shipbuilding Co. its slogan "The Oil Industry's Shipyard."

WELDING OF ALUMINUM

Cumberland, Ind.—Mr. Joseph W. Kehoe AWS, section manager, Metals Joining Laboratory, Westinghouse Electric Corp., Pittsburgh, Pa., was the guest speaker at the March 25th dinner meeting of the *Indiana* Section held at Buckley's Restaurant in Cumberland.

Mr. Kehoe's topic for the evening was "Single Phase Resistance Welding of Aluminum," in which he covered

INDIANA SECTION HEARS KEHOE ON ALUMINUM WELDING

Indiana Section officers and principal speaker at the March meeting. *Left to right:* M. G. Schaefer, 2nd Vice-Chairman; Paul Grubbs, Treasurer; Gil Foster, 1st Vice-Chairman; J. W. Kehoe; C. Heffernon, Technical Secretary; Jim Solotin, Chairman; Ray Wirt, Program Chairman.

ACCO products

3 Big Reasons for Buying PAGE Automatic Welding Wire

1. Packaged to fit your particular requirements

2. A wide range of analyses to fit a particular job

3. Greatest convenience — you can buy from local stocks

There is every reason why you should look to PAGE for your automatic welding wire needs. For PAGE not only manufactures wire in an extremely wide range of analyses, but packages them in a variety of ways for the most complete protection and convenience in handling and stocking. PAGE Distributors throughout the country carry stocks — this means savings for you, in ordering time and in inventory investment.

Shown above are some of the handy ways PAGE Automatic Welding Wire is packaged...There are lightweight, durable Leverpaks, which provide perfect protection against coil distortion or wire corrosion. They're easily opened and resealed, roll easily, stack perfectly and take a minimum of floor space.

There are single and pallet-mounted (1,000 lb., 2,000 lb., 3,000 lb.) coils, each wrapped in waterproofed paper and held secure by steel strapping; thread-wound, 25-pound reels to fit popular machines; also, coils in individual cardboard cartons, available singly or palletized for handling by fork-lift truck.

Page Offers 26 Analyses in Automatic Welding Wire

In order to provide you with *exactly* the correct automatic welding wire for your specific requirements—no matter how "special" or "different" they may be—PAGE offers no less than 26 different analyses from which to choose. These "cover the waterfront" of applications: heavy automatic submerged arc...light manual submerged arc ...inert gas manual and automatic, tungsten or metal arc.

Carbon Steel • Any carbon from Armco (.025 max.) to high carbon (.90—1.10). All standard AISI analyses in between.

Low Alloys • All the most popular welding grades

Stainless • AISI grade. Other types on request

Following is a list of the *26 analyses* in which PAGE Automatic Welding Wire is readily available:

Page A-S-Armco	Page A-S-110
Page A-S-6	Page A-S-15
Page A-S-10	Page A-S-15-MO
Page A-S-17	Page A-S-3½-Nickel
Page A-S-20	Page A-S-6150
Page A-S-65	Page A-S-4130

Page NAX-9115
Page-Allegheny A-S-Type 304
Page-Allegheny A-S-Type 308
Page-Allegheny A-S-Type 308 ELC
Page-Allegheny A-S-Type 309
Page-Allegheny A-S-Type 310
Page-Allegheny A-S-Type 316
Page-Allegheny A-S-Type 316 ELC
Page-Allegheny A-S-Type 347
Page-Allegheny A-S-Type 348
Page-Allegheny A-S-Type 410
Page-Allegheny A-S-Type 420
Page-Allegheny A-S-Type 430
Page-Allegheny A-S-Type 502

Details of all these analyses are contained in our new Folder DH-402. Write for it!

from Page's Wide Range You Can Get Exactly the Analysis You Need for Each Welding Job

• The *right* electrodes and the *right* rods for every welding job! That is what you must have for perfect operation—and that is what you can expect from the wide range offered by PAGE. Choose what you need from this complete line:

Gas Welding Rods

Armco Gas (GB-45)	Page Armco
Mild Steel (GA-50)	C Gas
Low Alloy (GA & GB-60)	Hi-Tensile M
3½% Nickel (GB-65)	3½% Nickel
.55—.65 Carbon	Medium Carbon
.90—1.10 Carbon	High Carbon
Manganese Bronze	Manganese Bronze
Naval Bronze	Naval Bronze
Stainless Steel	According to AWS analysis

Any Page A-S Automatic Grade in 36" Lengths

Bare Electrodes

Armco	Page Armco
Low Carbon	Page "CE"
.13—.18 Carbon	Page "B"
.55—.65 Carbon	Medium Carbon
.90—1.10 Carbon	High Carbon

Metal Spray Wire

Armco	Page Armco
.10 Carbon	#10
.28 Carbon	#25
.40 Carbon	#40
.60 Carbon	#60
.80 Carbon	#80
1.00 Carbon	#100
3½% Nickel	3½% Nickel
Manganese Bronze	Manganese Bronze
Naval Bronze	Naval Bronze
Stainless Steel Metal Spray	According to AWS Analysis

Convenient Service from Local Stocks

• Whenever you are in need of automatic welding wire, electrodes or welding rods, you can get them quickly and easily from your nearby PAGE Distributor—no matter what part of the country you live in.

PAGE Distributors carry ample stocks from which your requirements can be filled without delay or inconvenience to you. This handy service not only saves you time in getting what you need, but makes it unnecessary for you to make a sizeable investment in inventory. Thus, your nearby PAGE Distributor is able to make double savings for you—a saving in time and a saving in actual dollars.

Get the full Analysis List

All the 26 analyses of PAGE Automatic Welding Wire are set forth in complete detail in new **Folder DH-402.** A free copy of this informative folder will be sent to you on request. Write to our Monessen, Pa., office.

FREE

ACCO

Page Steel and Wire Division
AMERICAN CHAIN & CABLE

Monessen, Pa., Atlanta, Chicago, Denver, Detroit, Houston, Los Angeles, New York, Philadelphia, Portland, Ore., San Francisco, Bridgeport, Conn.

for Better Value

many phases of this subject from the cleaning of the metal to welding in accordance with the government standards. Mr. Kehoe was recognized for his extensive contributions to the art of metals joining. He is a member of the AWS Resistance Welding Committee and is chairman of the Subcommittee on the welding of steel.

QUIZ THE EXPERTS

Indianapolis, Ind.—The annual "Quiz the Experts" program of the *Indiana* Section was held on April 22nd at the Hotel Antlers in Indianapolis. Participating teams came from Dayton, Ohio; Detroit, Michigan; Marion, Ohio and Anthony Wayne Section. The Indiana Section team served as judges.

The buffet dinner was preceded by a "Hospitality Hour" with a short business meeting following the dinner. The quiz program covered questions on all phases of welding—arc, resistance, gas, soldering and brazing. The winner was the Detroit Section.

PAST CHAIRMEN'S NIGHT

Cumberland, Ind.—The May meeting of the *Indiana* Section held on May 20th at Buckley's Restaurant in Cumberland, was designated as Past-Chairmen's Night and all of these men were honored for their guidance throughout the year.

Election of officers was also held with the following results:

Chairman—G. L. Foster
1st Vice-Chairman—M. G. Schaefer
2nd Vice-Chairman—E. F. Holt
Treasurer—Fred Watts
Secretary—Mrs. Mercedes Spotts

A plaque was also presented to the retiring treasurer, Paul Grubbs, who had served the Section faithfully from 1940 to 1955, but who had been forced to retire because of ill health.

The guest speaker of the evening was George Sipple, senior experimental metallurgist, Material and Process Section, Metallurgical Department, Allison Division, General Motors Corp., Indianapolis, Ind. His topic for the evening "Welding Metallurgy," covered the welding problems involved in the manufacture of jet aircraft engines from a metallurgical standpoint. He not only stated the problems and gave the solution but went into great detail as to why.

NEWLY ELECTED OFFICERS

Des Moines, Iowa—The election of the following officers and committee chairmen has been announced by the *Iowa* Section:

Chairman—Red C. Lowe
1st Vice-Chairman—Ed Looney
2nd Vice-Chairman—L. P. Faddis
Secretary-Treasurer—D. E. Shapter
Chairman Membership Committee—L. P. Faddis
Chairman Program Committee—Ed. Looney
Technical Representative—Alan F. Busto

LEHIGH VALLEY OFFICERS

Bethlehem, Pa.—The *Lehigh Valley* Section announces the election of the following officers and committee chairmen:

Chairman—V. P. Edwardes
1st Vice-Chairman—R. I. Fluck
Secretary-Treasurer—R. A. Bartholomew
Chairman Membership Committee—W. D. Price
Chairman Program Committee—R. I. Fluck
Technical Representative—C. L. Kreidler

ELECTION OF OFFICERS

Madison, Wis.—The final meeting of the first year of the *Madison* Section was held on May 26th at the Eagle's Club in Madison. This was a distinctive meeting in that it was the first Ladies' Night for the group. This will be an annual affair hereafter. Election of new officers was one of the prime business functions of this meeting. The ladies were a welcome addition to the social part of the meeting which included dinner, dancing and entertainment.

Past Chairman Walter Griskavich, was given an award in appreciation for his past efforts on behalf of the Section. It was the unanimous opin-

MADISON SECTION ANNOUNCES NEW OFFICERS

Pictured above are the new officers of the Madison Section. *Left to right:* 2nd Vice-Chairman Arnold Ehle, Chairman Howard Adkins, Past-Chairman Walter Griskavich, Executive Board member John Cairnes, First Vice-Chairman Fred Thieler and Secretary-Treasurer Ray Knudtson. Executive board members not shown are Ted Glesing, Joe Weyrough and Charles Dreutzler

NEW OFFICERS INSTALLED BY NEW ORLEANS SECTION

These are the new officers who were installed at the May meeting of the New Orleans Section: (*Left to right*) J. M. Shilstone, M. B. Crawford, R. P. Wilson and C. W. Gray, members at large; W. G. Blackwell, chairman, S. L. Ritter, treasurer, T. L. Fatland, member at large, R. A. Flautt, Jr., vice-chairman. Not present in picture W. A. Massimini, secretary.

ion of the members that "Wally" had done a tremendously effective job in welding together the new Section in true AWS fashion.

TOOLING FOR WELDING

New Orleans, La.—Anthony K. Pandjiris of the Pandjiris Weldment Co., St. Louis, Mo., gave an excellent talk on "Tooling for Automatic Welding" at the May 24th dinner meeting of the *New Orleans* Section held at the Engineers' Club, DeSoto Hotel.

Installation of officers for 1955–56 also took place at this meeting, as follows:

Chairman—W. G. Blackwell
Vice-Chairman—R. A. Flautt, Jr.
Secretary—W. A. Massimini
Treasurer—S. L. Ritter
Members at large: J. M. Shilstone, M. B. Crawford, R. P. Wilson, C. W. Gray, T. L. Fatland

NEWLY ELECTED OFFICERS

New York, N. Y.—The *New York* Section announces the election of the following officers and committee chairmen for the fiscal year:

Chairman—John Mikulak, Worthington Corp.
1st Vice-Chairman—J. T. Stewart, Whitehead Metal Products Co.
2nd Vice-Chairman—E. W. Axthelm, The Linde Air Products Co.
Secretary-Treasurer—G. Metterhauser, Air Reduction Sales Co.
Chairman Membership Committee—A. L. Seiden, Architect
Chairman Program Committee—J. L. Menson, Combustion Engrg. Co.
Technical Representative—W. B. Kriewall, Permagile Corp. of America

WHAT'S NEW IN BRAZING

Bucyrus, Ohio—The May meeting of the *North Central Ohio* Section was held at the American Legion in Bucyrus on May 6th. Fifty-five members and guests were present to hear Orville T. Barnett [M'52], chief of welding research at Armour Research Foundation, Chicago, Illinois. Mr. Barnett's subject "What's New in Brazing," proved very informative and interesting to all. A movie entitled "The Iron Horse Goes North" was shown through the courtesy of the M. A. Hanna Co.

ANNUAL MEETING

Erie, Pa.—At the annual meeting of the *Northwestern Pennsylvania* Section held on May 25th, the following officers were elected for the ensuing year:

Chairman—Robert K. Allen, General Electric Co.
1st Vice-Chairman—George E. Danner, Erie Forge Co.
Secretary-Treasurer—W. R. Boyd, Boyd Welding Co.
Assistant Secretary-Treasurer—John S. Lentz, Boyd Welding Co.
Director, 2 year term—Knute T. Lindquist, General Electric Co.
Director, 1 year term—Otto Finke, Finke's Welding Service

PORTLAND ELECTION

Portland, Ore.—At the final meeting of the 1954–55 season, the *Portland* Section announced the election of the following officers for the coming year:

Chairman—George A. Conner
Vice-Chairman—W. L. Wyman
Secretary—Earl Bobbitt
Treasurer—L. Kissler

Mr. LaMotte Grover [M'52], of the Air Reduction Co., gave a very interesting slide talk on the new structural steel materials that are now available. The talk covered the welding procedures, current practices in design and construction methods developed to take advantage of the new steel.

NIAGARA FRONTIER OFFICERS

Buffalo, N. Y.—The *Niagara Frontier* Section announces the election for the fiscal year of the following officers and committee chairmen.

Chairman—Donald D. Campbell
1st Vice-Chairman—Gerald E. Claussen
2nd Vice-Chairman—Donald F. Baumler
Secretary-Treasurer—Robert Siemer
Chairman Membership Committee—Roger Stouffer
Chairman Program Committee—James J. Russ
Technical Representative—Lewis F. Pettit, Jr.

RECENT DEVELOPMENTS IN WELDING

San Francisco, Calif.—The March dinner meeting of the *San Francisco* Section was held on April 4th at El Jardin. The Section was honored by the presence of President J. H. Humberstone who briefly discussed the numerous activities of the Society. Also present was National Secretary J. G. Magrath.

The theme of the technical program was "Recent Developments in Weld-

THE MOST ADVANCED AUTOMATIC FLUXING SYSTEM EVER OFFERED FOR BRAZING

EASY WAY TO LOW COST

• All-State "Jet Flux" Auto-Dispenser No. 1 as you get it from the factory . . . is a pressure cylinder complete with automatic dispenser, controls, and hose with connections . . . ready to tie in, without special tools, to single or multiple brazing stations.

• Only one supply item—All-State "Jet Flux"—fluxes brazing work automatically through the fuel gas.

Ask to see "Jet Flux" Demonstrated by your Distributor

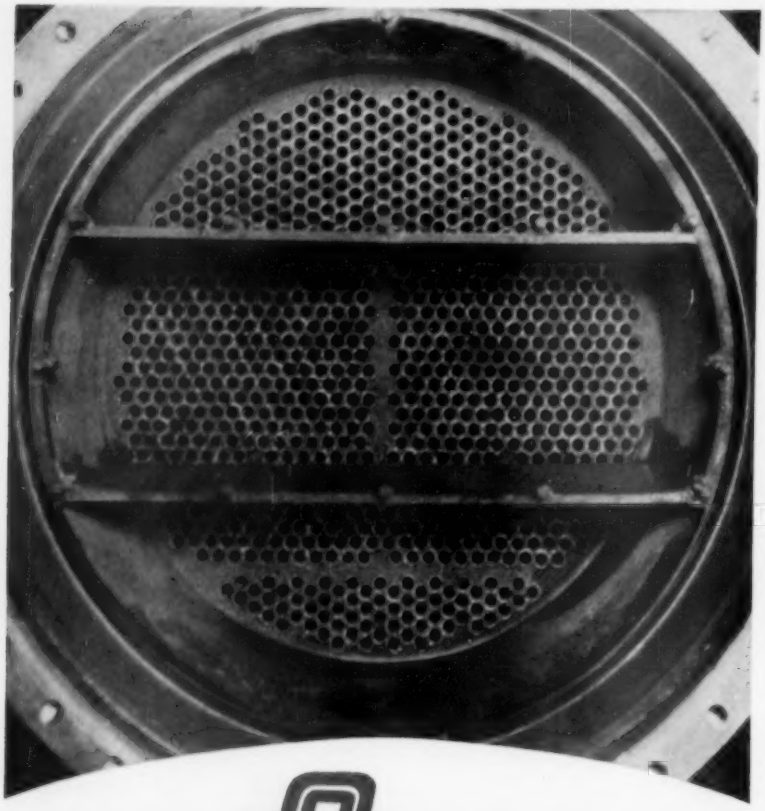
A-S DISTRIBUTORS EVERYWHERE

All-State

ALL-STATE

WELDING ALLOYS CO., INC.
White Plains, N. Y.

Save time, money and worry when welding stainless steels



WELD WITH ARCOS

STAINLESS ELECTRODES

Arcos controls in manufacture guarantee highest quality weld metal easily deposited. Widest electrode selection in the industry enables you to meet accurately the physical, chemical and metallurgical requirements of every job. Special ELECTRO-PAK prevents moisture pickup and chipped coatings in shipment and storage, also provides resealable feature. ARCOS CORPORATION, 1500 South 50th Street, Philadelphia 43, Pa.

ing." A summary of the latest developments in the welding industry was given by two well qualified members. Charles B. Robinson AWS, of the Air Reduction Pacific Co. discussed the new developments in inert gas welding and Cecil W. Doggett AWS, of the Linde Air Products Co. covered the subject "Submerged Arc Welding." Eighty members and guests were present at this highly interesting and educational meeting.

AUTOMATIC WELDING

San Francisco, Calif.—The *San Francisco* Section held its April dinner meeting on April 25th at the Engineers' Club. Coffee speaker was W. D. "Bill" Russell AWS, instructor of mechanical engineering, City College of San Francisco. Mr. Russell gave an interesting discussion on the training of technicians for industry in the Junior Colleges. Speaker on the technical program was A. K. Pandjiris AWS, president of Pandjiris Weldment Co. and past-chairman of the St. Louis Section. The title of Mr. Pandjiris's talk was "Weldmation," which is the proper application of automatic welding equipment through proper fixturing. In the course of his talk, Mr. Pandjiris discussed what can be achieved cost wise and production wise by use of special fixture designed for a particular welding application. Slides were shown of many different fixtures for automatic welding which his company has designed and built.

NEWLY ELECTED OFFICERS

Berwick, Pa.—The following officers and committee chairmen have been elected by the *Susquehanna Valley* Section for the fiscal year:

Chairman—George E. Reed, ACF Industries, Inc.
1st Vice-Chairman—B. G. Dann, Jr., Hendricks Mfg. Co.
Secretary—Andrew J. Furman, Commercial Gas Corp.
Treasurer—Robert P. Schweyer
Chairman Membership Committee—Stanley R. Bunn, Commercial Gas Corp.
Chairman Program Committee—T. W. McHale, Lummus Co.
Technical Representative—Lewis S. Bussel

TUCSON ELECTION

Tucson, Ariz.—At a meeting of the *Tucson* Section held on May 24th announcement was made of the election of the following officers for the coming year:

Chairman—Robert S. Smith

1st Vice-Chairman—George Hunt
2nd Vice-Chairman—Charles Condron
Secretary—Dean Tillotson
Treasurer—Albert Deann
Executive Committee, 1 year—A. W. Barnier, Richard L. Smith, and Johnny F. Cornelius
Executive Committee, 2 years—Joe Brennan, Dewey White and Ramon M. Camacho

The newly elected chairman took the chair and a general discussion followed on plans for an award by the Section to the outstanding welding student. It was suggested that all high schools in Southern Arizona be invited to participate.

The outgoing chairman, J. H. Brennan, was complimented on his successful term of office.

ELECTION OF OFFICERS

Springfield, Mass.—The *Western Massachusetts* Section announces the election of the following officers and chairmen of committees:

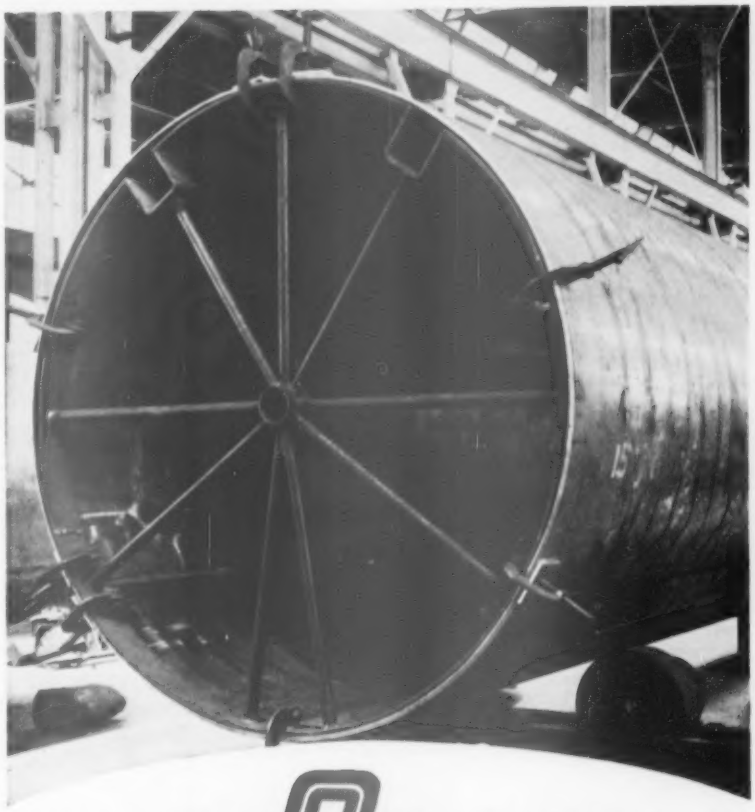
Chairman—Walter A. Gutowski
1st Vice-Chairman—Alden Safford
Secretary—Leon W. Jaeger
Treasurer—R. Frederick Fountain
Chairman Membership Committee—Sidney Low
Chairman Program Committee—Norman Cote
Technical Representative—C. A. Keyser

NEW OFFICERS

York, Pa.—The following officers and directors have been elected by the *York Pennsylvania* Section:

Chairman—William T. DeLong
Secretary—Edwin R. Szumachowski
Program Chairman—Cameron C. Mathias
Membership Chairman—Paul A. Eveson
Technical Director—Richard K. Lee
Special Activities Chairman—Frank A. Logue
Past-Chairman—Paul LeRoy Stumpf
Vice-Chairman—Walter W. Lilly, Jr.
Treasurer—Charles W. Allen
Publicity Chairman—Austin F. Leach
Entertainment Chairman—C. E. L. Kerchner
Directors, 1 year—William Zinkand, David F. Walters, Roger W. Tuthill and Philip C. Ruby
Directors, 2 years—Clyde R. Renshaw, Charles C. Hyde, Paul A. Eveson, John O. Cavanaugh, Cameron C. Mathias and Austin F. Leach

How to improve quality on every aluminum job welded by inert gas



WELD WITH ARCOS

ALUMINUM SPOOLED WIRE

The advantages of aluminum weld-fabrication are many. But only a quality weld metal can produce them with maximum benefit. Arcos manufacturing controls applied to ALUMAR Spooled Wire are a sure guarantee. Within a critically controlled range you can meet every characteristic with "peace of mind". ARCOS CORPORATION, 1500 South 50th Street, Philadelphia 43, Pa.

New Members

Effective June 1, 1955

MEMBERSHIP CLASSIFICATION

A—Sustaining Member B—Member C—Associate Member D—Student E—Honorary Member F—Life Member

ANTHONY WAYNE

Myrick, Carl (B)

ARIZONA

Griffen, Frank W. (B)

BOSTON

Miller, Robert C., Jr. (B)
Smith, William Vernon (B)

BRIDGEPORT

Bango, Jules (C)
De Paola, Dominic (B)
Flagge, John T. (B)
Monde, Robert R. (B)

CANADA

Brown, Gordon J. (C)
Eberts, James E. (B)

CHICAGO

Fitch, James C. (C)
Michelon, Al (C)
Saks, Carl J. (B)

CINCINNATI

Bacon, Franklin J. (C)
Cashen, E. E. (C)
Davison, Lewis A., Jr. (C)
Fortini, Louis (B)
Galloway, Sidney Howard (C)
Golatzki, Lewis (C)
Hines, John H. (C)
Kappes, R. B. (C)
Kelley, John D. (C)
Lemmons, Myron (C)
Patsfall, R. E. (B)
Porter, Richard T. (C)
Reiff, Melvin C. (C)
Reif, Thomas J. (B)
Robbins, Robert E. (C)
Runnebaum, Ben (C)
Schwegman, Ralph H. (C)
Schroeder, Jack C. (C)
Woodlock, Paul B. (C)

CLEVELAND

Duer, Earl W. (B)
Ringenbach, Henry A. (B)
Weichel, Lester (B)

COLORADO

Kofoed, Warren D. (B)
Sayers, H. C. (C)

COLUMBUS

Davis, David M. (D)
Durzo, Frank J. (A)
Lonzo, Kenneth (C)
McPherson, Robert F. (D)
Wilson, Clyde W. (D)
Wong, Harry, Jr. (D)

DALLAS

Cerf, Harry F. (B)
Sorrells, J. C. (B)

DETROIT

Cameron, Alex T. (B)
Goodman, Gilbert (C)
Johnson, Edwin R. (B)
Kollar, James A. (B)
Laurie, Dorothy (B)
Satir, Kemal (B)
Sollie, Stephen J. (C)

EAST TEXAS

Walker, James H. (D)

FOX VALLEY

Lee, George K. (C)
Meeleus, Harry G. (C)

HOLSTON VALLEY

Bible, Eugene (C)
Chandler, John L. (C)
Edens, James D. (C)
Hendrix, George A. (C)
Muse, Bill T. (B)
Muse, Mayland H. (B)
Simerly, Louie F. (C)

HOUSTON

Ellison, Noble H. (C)
Lee, P. A. (B)
Robbins, R. B. (C)
Switzer, Grayson (C)
Wiggins, Wm. R., Jr. (B)

INDIANA

Pollock, A. B. (B)

IOWA-ILLINOIS

Burmeister, Howard M., Jr. (B)
Nyberg, Lloyd P. (B)

KANSAS CITY

Hall, James R. (C)
Hoyt, Robert T. (C)
Rybolt, Myron C. (C)

LONG BEACH

Montgomery, Robert R. (B)
Slack, Ellis G. (B)

LONG ISLAND

Angelone, Dominick A. (C)

LOS ANGELES

Barton, George K. (C)
Bondesen, Albert J. (B)
Carlson, C. A. (B)
Cromer, W. M. (B)
Durfee, Earl, Jr. (B)
Ittner, Nelson C. (B)
Levy, Alan V. (B)
Oleno, Peter C. (C)
Palmer, George (C)

MADISON

Kufrin, Richard W. (B)

MARYLAND

Hopkins, Joseph Wm., Jr. (C)
Kidwell, Richard F. (C)
Miles, Robert E. L. (C)

MILWAUKEE

Lamm, Paul F. (B)
Vincent, Roy E. (B)

NEW JERSEY

Hartmann, Bernie (B)
Sharp, William A. (B)
Smith, James F., Jr. (C)
Townsend, Edward M. (B)
Webb, James P. (B)

NEW ORLEANS

Burke, Frank E. (B)
Evans, Joel C. (C)
Smith, Jason P. (B)

NIAGARA FRONTIER

Rosage, Herman F. (C)

NORTH CENTRAL OHIO

Mefferd, Von L. (C)
Meyer, Omar E., Jr. (B)
Newhart, C. R. (C)
Smith, Henry R. (B)

NORTHEAST TENNESSEE

Waugh, R. C. (C)

NORTHERN NEW YORK

Robelotto, Salvatore (D)
Ruediger, Brent A. (B)
Rzant, Adolph William (B)

NORTHWEST

Hakala, William A. (C)
Himrick, Arthur O. (B)
Mankowski, B. J. (A)

OKLAHOMA CITY

Chapman, George W. (D)
Davis, Riley E., Jr. (D)
Fisher, George H. (D)
Johnson, Jesse V. (D)
Jones, Duane C. (D)
McCune, Nadeau L. (D)
McMullen, Billy J. (D)
Oaks, Donald (D)
Price, F. L. (D)
Steward, Jimmie (D)
Strickland, Joseph Carl (D)

PEORIA

Barnes, David O. (B)

PHILADELPHIA

Brown, William H. (C)
Eisenmann, Frederick A. (B)
McClain, William A. (C)
Trippany, Donald C. (C)
Walberg, George M. (C)

PITTSBURGH

Cummins, Don E. (C)

PORTLAND

Barton, E. (B)

PUGET SOUND

Kasen, Maurice B. (C)
Orth, Douglas E. (C)

RICHMOND

Davis, Wade O. (B)
Dodge, Donald C. (C)

ROCHESTER

Kanzler, Herbert (C)

SAINT LOUIS

Burrow, E. Carl (C)
Loughin, Marshall I. (C)
Wright, Fred C. (C)

SALT LAKE CITY

Capener, Homer (D)
Capener, La Mar (D)
Hill, Don William (C)
Kunz, John R. (D)
Peterson, Lowell Jack (D)
Shelton, Ross (D)
Thompson, Ortize N., Jr. (D)
Wood, Neal (D)
Woodruff, Dale (D)
Woodruff, Ivan L. (D)

SAN FRANCISCO

Croswell, A. M. (A)
Doleman, Edward (B)

SANGAMON VALLEY

Burleson, H. T. (B)
Fathauer, Herbert H. (C)

SANTA CLARA VALLEY

Alexander, Myron Edward (B
Downing, D. H. (C)
Hitt, S. W. (B)
Marks, Lloyd C. (B)

SOUTH FLORIDA

Blackstone, Douglas V. (B)
Brown, Roy E. (B)
Freedman, B. D. (B)

Question-Mark* FITTINGS

. . . A BARGAIN?

They could cost you your reputation!

***QUESTION-MARK FITTINGS**

Who is manufacturer?
How about his reputation?
What is his experience?
Does he give service?
Does he offer complete line?
Is stock available nearby?
Do fittings meet U. S. standards?
Are dimensions accurate?
Is circularity true?
Equal to strength of pipe?
Are fittings permanently marked with manufacturer's trademark and material designation?

YOU RUN THESE RISKS WITH THESE UNKNOWN PRODUCTS:

Failure in service . . . work stoppage . . . waste.
Impaired efficiency due to improper design.
Non-uniformity . . . wastes manhours.
Poor availability . . . costly in emergencies.
Short-line supply . . . handicaps selection.
Lack of service or responsibility.
Lack of engineering help on piping problems.
Lack of cost-cutting advancements.

Presented in the interests of piping safety and economy by

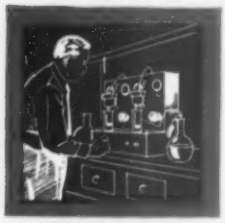
TUBE TURNS

A Division of National Cylinder Gas Company
LOUISVILLE 1, KENTUCKY

. . . Producer of **KNOWN VALUES**

Remember the trade-marks "tt" and "TUBE-TURN" are applicable only to products of TUBE TURNS.

Tube Turns' nearby complete stock SAVES YOUR PURCHASING TIME



Tube Turns' pioneering research GIVES YOU ADVANCED PRODUCTS

Tube Turns' engineering help GIVES YOU COST-CUTTING IDEAS

How to safeguard your piping and get *more for your money*

When you buy TUBE-TURN® Welding Fittings and Flanges, you get these known values:

TOP QUALITY AND SAFETY **RESPONSIBILITY** **PRECISE UNIFORMITY**
ENGINEERING SERVICE **WIDE SELECTION** **LOWEST-COST PERFORMANCE**
PROMPT DELIVERY **DESIGN ADVANCEMENTS**

They are made in U.S.A. and are identified by the trade marks shown above.

They meet ALL American Standard and Safety Code requirements.

They are engineered to give maximum strength and performance and in many cases exceed requirements by generous margins.

To get *more for your money* in welding fittings and flanges, specify the leading brand and buy from your trusted Tube Turns' Distributor.

The Leading Manufacturer of Welding Fittings and Flanges

TUBE TURNS

LOUISVILLE 1, KENTUCKY

A Division of National Cylinder Gas Company

DISTRICT OFFICES: New York • Philadelphia • Pittsburgh • Cleveland • Detroit • Chicago • Kansas City • Denver
Los Angeles • San Francisco • Seattle • Atlanta • Tulsa • Houston • Dallas • Midland, Texas

"TUBE-TURN" and "tt" Reg. U.S. Pat. Off.

Hose, Harold C. (B)
McLean, George J. (B)
Roy, Robert H. (C)
Valverde, D. E. (B)
Wheeler, Ben (B)

SYRACUSE

Marcy, Alfred R. (C)

TOLEDO

Perch, Daniel F. (B)
Rothfuss, Fred D. (C)

TUCSON

Douglas, Brainard E. (C)

WASHINGTON, D. C.

Andrews, George R. (C)
Becraft, C. Edwin (C)
Thomas, Victor (B)

WESTERN MICHIGAN

Dauser, Robert O. (C)
Gill, Harry M. (C)
Masck, William A. (C)
Paul, Claude L. (C)
Salatka, George A. (C)
Sanford, R. F. (B)
Urbon, Ernest R. (B)

WICHITA

Nelson, Herschel E. (C)
Newkirk, Ralph L. (C)
Petty, James E. (C)
Scott, Gene J. (B)
Ward, Wm. R. (C)

NOT IN SECTIONS

Jain, Ramji Dass (C)
Kazi, Mahmud I. (C)
Majumdar, Birendra Nath (C)
Reddy, Agasthi Ranga (B)
Sarmah, Harrish Chandra (C)
Sen, Kamal Kumar (C)
Toyofuku, Kiyotami (B)

Members Reclassified

During the month of June

IOWA

Elliott, Edwin G., Jr. (C to B)
Kuhr, G. E. (C to B)

PHILADELPHIA

Thomas, R. D. (B to A)

ABSTRACTS OF CURRENT PATENTS

prepared by V. L. Oldham

Printed copies of patents may be obtained for 25¢ from the Commission of Patents, Washington 25, D. C.

2,710,327—Stitching Head for Welder—Richard A. Powley, Birmingham, Mich., assignor to Chrysler Corp., Highland Park, Mich.

This patent is on an electrode supporting assembly for attachment to an electrically operated spot-welding machine. The attachment comprises a spindle of inverted T-shaped in cross section having connected shaft and disk portions. An electrode holder is mounted on the spindle disk portion for rotation therewith and it includes means for positioning the holder on the spindle disk face at a variable radial distance from the axis of rotation of the spindle.

2,710,328—Welding Process—Robert E. Semple, Temple City, Calif., assignor, to Beckman Instruments, Inc., Fullerton, Calif.

Semple's patent relates to a method of welding two small metal filaments near the range of sizes in which the use of optical magnification is desirable for quantity production. The method comprises narrowing a gap between two filaments to be welded together and with the filaments being electrically connected to opposite sides of a charged capacitor. The filaments are moved toward each other until a spark discharge occurs across the gap and the rate of narrowing of the gap is so controlled that, at the time of the spark discharge, substantially no pressure is applied to the filaments in the region of the spark.

2,710,443—Method of Making a Restricted Orifice Tube Joint—Thomas B. Webb, Beckenham, England, assignor to The Babcock & Wilcox Co., Rockleigh, N. J.

This patent relates to the provision of a connection between the interior of a tubular member and the interior of a vessel through a restricted orifice. The method comprises positioning a tubular stub with a chamfered surface outwardly adjacent to a wall of the vessel so as to define therewith an annular welding space, and joining the stub to the wall by fusion depositing weld metal within such annular welding space. The weld metal is removed from the root of the weld by a boring operation initiating within the stub and continuing at substantially the same diameter as the initial bore throughout the remaining length of the stub and for a short distance into the vessel wall. The remaining thickness of the vessel wall is then formed to provide an orifice of restricted cross sections to provide communication between the interior of the vessel and the bore of the stub.

2,710,901—Method and Machine for Brazing Electric Iron Body Assemblies—Murray Ireland, Elgin, Ill., assignor to McGraw Electric Co. Elgin, Ill.

In this patent, a machine for brazing a sadiron sole plate and pressure plate assembly together is provided. The machine includes heating means for supplying brazing heat to the margins of the plate assembly, and opposing pressure members having contacting faces of mica. These mica faces are on opposite sides of the heating means and are adapted to clamp the plate assembly together to subject it to desired pressure.

2,710,902—Rod Feed for Manual Arc Welding—Frank J. Pilia, West Orange, N. J., assignor to Union Carbide and Carbon Corp.

A method of arc welding with a torch movable along a line of weld is disclosed and includes the step of striking an arc to heat a portion of a workpiece and form a weld puddle. A filler rod is fed through the weld puddle by suitable guide means and the guide is maintained at an acute angle to the surface of the workpiece. The torch is propelled along the line of weld in the direction opposite to the direction of rod feed by reaction of the component of force of the rod feed parallel to the work surface.

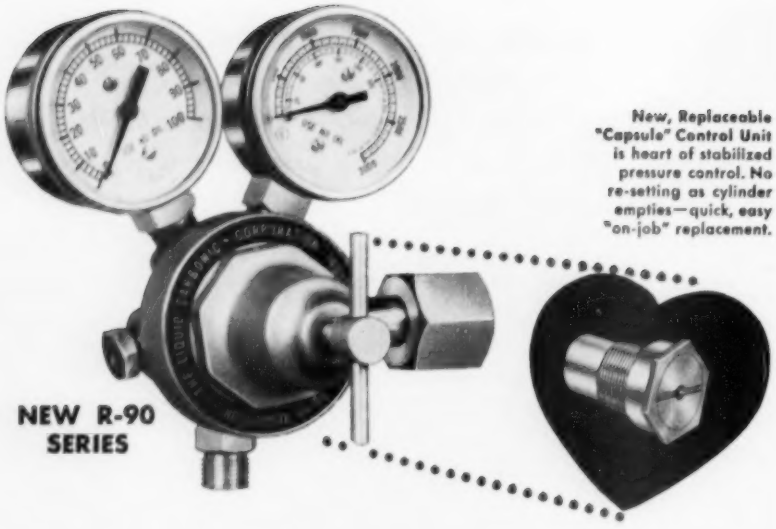
2,710,903—Work Holding Apparatus for Flash-Butt Welding Machine—Melvin M. Seeloff and Robert Anderson, Warren, Ohio, assignors to The Taylor-Winfield Corp., Warren, Ohio.

This patent relates to an electric resistance welding machine having a rigid frame, a fixed die member, and a movable die member. Quick acting means are provided for moving the movable die member toward and away from the fixed die member. A retractible high power actuating device is present for urging the movable die member toward the fixed die member under high pressure, while a rigid retractible means mechanically interconnects the high power device with the frame. The movable die can be moved independently of extending or retracting movement of the high power device when this rigid retractable means is in a retracted, inoperative position.

2,710,904—Pressure Setting Fixture—Douglas Crane, Zionsville, Jack E. Griffis, Bethlehem, and Francis A. Haggerty, Coopersburg, Pa., assignors to Western Electric Co., Inc., New York, N. Y.

A special welding fixture is disclosed in this patent and it comprises means on a frame for holding a multi-part assembly in a predetermined position under a predetermined force. The assembly then can be locked in position and is adapted to have welding electrodes brought into association therewith for welding action.

2,711,466—Machine for Making and Attaching Electric Terminals—Harry Z. Marx, Dearborn, Mich.


New, Replaceable "Capsule" Control Unit is heart of stabilized pressure control. No re-setting as cylinder empties—quick, easy "on-job" replacement.
NEW R-90 SERIES

Single-Stage Cost 2-Stage Efficiency

NEW Gasweld

BALANCED-PRESSURE REGULATORS

- **Set It and Forget It!** Maintains stable delivery pressure as gas is consumed. Eliminates constant regulator re-adjustment.
- **Amazing Low Cost** due to new simplified design. Approximately 40% less than 2-stage, 20% less than most single-stage regulators.
- **New, "Capsule" Control Unit** permits easy, on-cylinder repair. Fewer repair parts to stock.
- **Safety Plus**—seats protected by non-flammable nylon filter. 2¼" nickel silver diaphragm. Forged body and bonnet. Easy to read gauges.

Ideal for practically every welding and cutting job. Made and guaranteed by LIQUID CARBONIC—famous for the highest quality. Write for additional details and prices.

LIQUID also produces Oxygen, Acetylene and other commercial gases including CO_2 in all its forms—Gas, Liquid and Solid (dry ice) for industrial use.

Liquid THE LIQUID CARBONIC CORPORATION
Industrial Gas Division
3100 S. Kedzie Ave., Chicago 23, Ill.

West of the Rockies: STUART OXYGEN CO., Los Angeles In Canada: IMPERIAL OXYGEN LTD., Montreal

This patented machine is adapted to automatically form and attach a terminal to a wire. The machine includes a punch press, hydraulic power means for actuating the press, and a multiple station die. Certain means continuously feed a strip of stock to the die which has a plurality of stations therein for forming a terminal on the strip. An intermediate station for welding the partly formed terminal to a wire is provided and the welding station includes electrodes secured to each of the shoes of the die. One or more stations are provided for final forming of the terminal and another station is provided for cutting the terminal from the strip stock.

2,711,467—Method of Producing Hard Facing Welded Deposits—Vincent T. Malcolm, Indian Orchard, Springfield, Mass., assignor to The Chapman Valve Manufacturing Co., Indian Orchard, Springfield, Mass.

Malcolm's patented process is for providing a base metal with a hard-facing alloy by a submerged-arc-welding operation. The method comprises using an electrode wire having a hardness of approximately 18 Rockwell "C" and comprising a chromium-cobalt alloy of low-carbon content. Such electrode wire is used in conjunction with a melt containing approximately 15% titanium oxide and 46.5% calcium and magnesium and silicon and aluminum oxide. Also, the melt includes approximately 15% limestone and approximately 11.5% ferro molybdenum and a balance of carbon and silica sand.

2,711,506—Slope Control for Loads such as Resistance Welds—Robert O. Johnsen and William B. Hills, Schenectady, N. Y., assignors to General Electric Co., a corporation of N. Y.

The patented control apparatus is for use in controlling loads, such as resistance welds and the controls include a pair of electric discharge devices having anodes and cathodes reversely connected in parallel with one another between one power supply conductor and one load conductor. A phase shift circuit is provided in the control, while several capacitors also are present in the control. A potentiometer is connected across the capacitors, and means responsive to the variation of voltage on the potentiometer vary the impedance value of the control apparatus in accordance with variation in the potentiometer voltage.

Join the Crowds

at the Bellevue-Stratford Hotel
Philadelphia, Pa.

October 17–21, 1955

•

Attend

1955 AWS National Fall Meeting

Automatic welding
at Solar Aircraft

CRUCIBLE stainless steel welding wire

for faster, cleaner, uniform weld quality

Save time and money . . . get better weldments with Crucible stainless steel welding wire. For Crucible welding wire is made by *steelmen* for optimum performance on the job.

You can get these superior welding wires for any type of automatic welding . . . in most stainless grades and sizes . . . and in spools, coils and cut lengths.

They're all quickly available through your nearby Crucible warehouse. Next time you need stainless welding wire call Crucible. *Crucible Steel Company of America, Henry W. Oliver Building, Pittsburgh 30, Pa.*

CRUCIBLE first name in special purpose steels

Crucible Steel Company of America

NEWS of The Industry

Welding Controls Distributors

Worthington Corp., Plainfield, N. J., is pleased to announce their appointment as exclusive national distributors for the line of welding controls manufactured by Mullenbach Division of Electric Machinery Manufacturing Co.

Effective June 1, 1955, all Mullenbach welding controls will be known as "Worthington-Mullenbach controls," and all future inquiries and purchases are to be directed to Worthington Corp., Welding Equipment Division, Plainfield, N. J.

The "Worthington-Mullenbach" line of welding controls includes the "Arc-trol," a portable remote control for adjusting amperage on all makes of arc welders, as well as a line of gas and water controls used in inert gas welding.

Reid-Avery Expands

The Reid-Avery Co., Inc., Dundalk, Baltimore 22, Md., is in the process of installing three new coiling machines of its own design, a new continuous electrolytic copper plating machine, a new Trauwood continuous annealing line, and is modernizing parts of the wire drawing facilities which now include the most modern Vaughn continuous six-pass machines.

The above equipment is expected to increase materially the production of all types of alloy and specialty wires in addition to the low-alloy and mild steel grades of rewound coils for automatic welding.

Changes in Nelson Sales Staff

The Nelson Stud Welding Division of Gregory Industries, Inc., Lorain, Ohio, announces several additions and transfers in its sales staff.

George E. Kennedy, field engineer in the Los Angeles territory the past four and a half years, has been appointed architectural representative on the West Coast. He will work directly with architects and engineers in the Los Angeles and San Francisco Bay areas in the development of designs and specifications incorporating the Nelson method.

Walter E. McArthur, dean of the Nelson field staff with 12 years of service in various sales-engineering capacities, has been transferred to Los Angeles after three years as field engineer in Cincinnati.

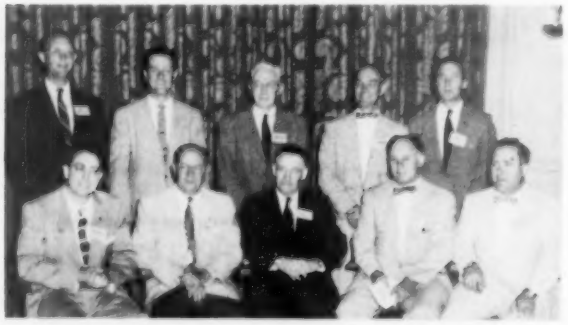
Herman S. Slinkard, in charge of Nelson sales for Lincoln Electric Co. in Sydney, Australia, the past eight years, will replace McArthur in Cincinnati.

ELEVENTH ANNUAL CONVENTION HELD BY NATIONAL WELDING SUPPLY ASSOCIATION IN CHICAGO, MAY 18–20, IS LARGEST TO DATE

The Convention was attended by 564 delegates. Here, is a general view of the Business Session

General view of the head table at the NWSA Annual Banquet. Toastmaster William A. Rice is shown presiding

R. P. Tarbell presenting silver pitcher to retiring NWSA president, James N. Alcock, during appropriate ceremonies

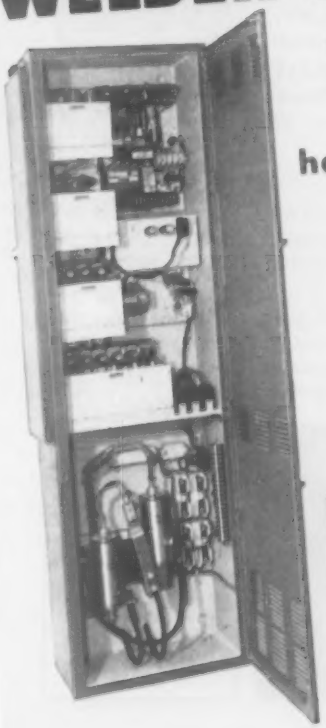


Officers and directors of NWSA elected at Convention. E. C. Caluwaert, shown seated in center, is the new president

A. O. Smith developed the exclusive techniques and machines for making non-corrosive "lined" pressure vessels for use in oil refineries, pulp digesters and chemical plants. The non-corrosive liners are spot welded to the inside of the vessel with thousands of welds.

Square D Welder Control proved itself in production by increasing speed, adding to the strength of the welds and reducing repairs

SQUARE D *Electronic* WELDER CONTROL



provided these improvements on one hard-to-weld alloy:

SPEED
Increased 22%!

STRENGTH
Increased 13%!

REPAIRS and REWORKING
Reduced 85%!

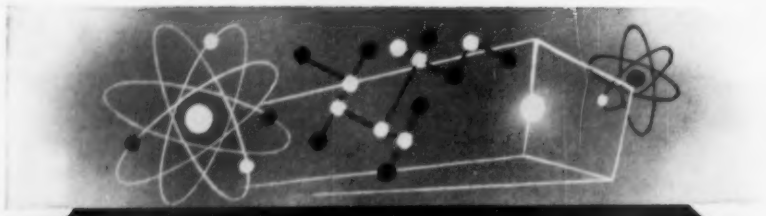
What is YOUR Precision Welding Problem?

- *Stainless Steel?*
- *Aluminum?*
- *Magnesium?*
- *Air-Hardenable Steels?*
- *Low-Carbon Steels?*
- *Aluminum-Magnesium Alloys?*

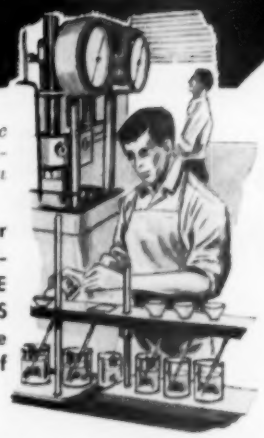
Square D has the control to meet your exact needs. Write us for Bulletin 8993. Address — Square D Company, 4041 N. Richards Street, Milwaukee 12, Wis.

ASK YOUR ELECTRICAL DISTRIBUTOR FOR SQUARE D PRODUCTS

SQUARE D COMPANY



CHAMPION
brings you the
WELDING ELECTRODES
of the Future . . . TODAY!!



Whatever your requirements in an arc welding electrode, CHAMPION'S Research and Engineering have designed a product that is tops in its class.

All CHAMPION ELECTRODES, whether MILD STEEL • IRON POWDER CONTACT • LOW ALLOY - HIGH TENSILE • LOW HYDROGEN • STAINLESS STEEL or HARD SURFACING have built in quality and excellence of performance.

We are especially proud in bringing to the fabricator **CHAMPION CROLOY ELECTRODES** which greatly minimize all of the problems formerly encountered in welding of chrome-moly steels. They offer —

Exceptional ease of handling in all positions. Highest possible mechanical properties; both as welded and stress relieved. Pass the most rigid radiographic examination. Reduce the former rigid restrictions on pre-heat and post-heat.

Header tee connections

For the full story on CHAMPION CROLOY or any of the other outstanding CHAMPION ELECTRODES mail your letterhead request at once to Dept. W.

THE CHAMPION RIVET COMPANY

CLEVELAND 5, OHIO — EAST CHICAGO, INDIANA

Vincent G. Probst, field engineer in the Denver area for two years, has been transferred to the Dallas, Tex., territory.

Ray M. Lucas, who has been in charge of industrial engineering for the production department at Nelson headquarters in Lorain during the past ten years, will replace Probst in Denver.

Linus C. Hansen has been appointed field engineer in the Chicago area. He has been an industrial sales engineer for the Latrobe Steel Corp. the past eight years.

G-E Announces New Sales Office

Establishment of a new direct-sales office and warehouse in Buffalo, N. Y., has been announced by the General Electric Welding Department, York, Pa.

W. G. Leaman, Buffalo metallurgist and welding engineer, has been named manager of the new office, located at 701 Seneca St. It is the regional outlet for the complete line of G-E equipment, electrodes and accessories.

K-G Distributors Appointed

The K-G Equipment Co., Inc., Allentown, Pa., manufacturers of welding and cutting equipment for industry and oxygen therapy equipment for the medical profession, announce the appointment of the following distributors for their industrial equipment: D & R Welding Supply Co., 612 Main St., Streator, Ill.; Burton C. French Co., 577 S. Diamond St., Mansfield, Ohio; Gano Welding Supply Co., Corner 4th & Railroad Sts., Charleston, Ill.; Keelor Steel, Inc., 909—9th St., S. E., Minneapolis, Minn.; Mercury Welders Service, 614 W. 25th St., Norfolk, Va.

Burdett Increases Facilities

The Burdett Oxygen Co. of Cleveland, Ohio, has just completed its new branch plant in Mansfield, Ohio. Situated at 45 E. Longview Ave., this new building replaces Burdett's former location at 210 N. Diamond St. This new and larger plant is a modern one-story, fireproof building 60 x 120 ft on a site 300 x 400 ft. The new location is in the center of the newest industrial development in Mansfield.

According to William H. Loveman, president of Burdett, features provided in the new plant include liquid oxygen vaporizing and pumping equipment and cylinder maintenance department. Display room for the convenience of customers and warehouse will carry the complete line of Burdox gases, welding, cutting and safety equipment and supplies.

William A. Kaiser is manager of the Mansfield branch.

PARTICIPATE IN FIRST CONVENTION OF CANADIAN WELDING SOCIETY

Honorable Robert H. Winters, Minister of Public Works, chats with some executive members ot the Canadian Welding Society at the exhibit of the Society's First Annual Convention. Left to right they are: J. M. Gulley, Publicity, A. S. Tuttle, Technical Papers, J. A. Brown, Convention Chairman, Hon. R. H. Winters, M. N. Vuchnick, Banquet, and Dr. J. Convey of the Dominion Department of Mines and Technical Surveys

Canadian Welding Society Holds 1st Annual Convention

Welding has played a top role in Canada's industrial development, the Hon. Robert H. Winters, Canadian Minister of Public Works, told the delegates to the first annual convention of the Canadian Welding Society at the president's banquet.

"It would be difficult indeed," said the minister, a former practicing engineer, "to touch on any phase of production involving the use of metals in which welding does not play a prominent role."

The Hon. Mr. Winters spoke on the history of welding and showed how major a share welding had contributed to the new industrial Canada. In fact Canada and welding in one way have grown up together since new welding practices are as recent as Canada's international stature.

The Welding Convention held its first convention June 6th and 7th as part of the Canadian International Trade Fair. Some 250 delegates attended from all parts of the country with Quebec and Ontario being most heavily represented. Fifteen major technical sessions were given while a special welding exhibit was shown. At the banquet Past-President E. A. Gill of Toronto handed the gavel to new president, R. F. Scott of Fort Erie.

New Welding Supply Association Formed

Joseph E. Martin, head of the Middlesex Welding Supply Co. of Everett, Mass., has been elected president of the newly formed New England Association of Welding Supply Distributors, Inc. Other officers and directors of the new association are: vice-president, S. A. Zane, Zane Weldcraft Supplies, Hartford, Conn.; treasurer, R. C. Anderson, Arlington, Mass.; secretary, William M. Foberg, William M. Foberg Co., Everett, Mass.; directors—E. S. Oppenheimer, Harris Calorific Sales Co., Boston, Mass.; Al Thomas, Northeastern Supply Co., Caribou, Me.; Henry Haywood, Welders Supply Co., Inc., Cambridge, Mass.; Roy Silver, Silver Welding Supply, Roslindale, Mass.; B. Sharples, Jonathan Handy Co., New Bedford, Mass.

The association has been formed by 23 of the leading welding supply firms located throughout New England.

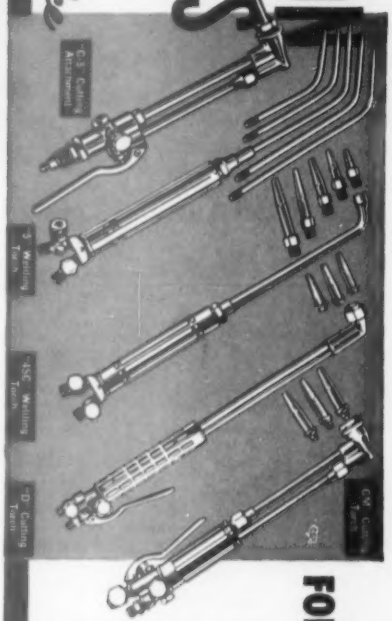
Tour Reorganizes Department

Sam Tour & Co., Inc., 44 Trinity Place, New York, announce the reorganization of their Nondestructive Testing Department. This department will be under the direct supervision of Sam Tour, president of the company. J. K. Bell, formerly director of this department, is no longer associated with the company.

The Nondestructive Testing Department of Sam Tour & Co., Inc. specializes in radiographic, ultrasonic, magnetic particle, fluorescent and dye penetrant methods of inspection in the laboratory and in the field "on the job." Mr. Tour is a member of the AMERICAN WELDING SOCIETY and participates actively in the work of the AWS Technical Activities Committee.

DOCKSON TORCHES

Built for Better Service



FOR OXY-ACETYLENE WELDING AND CUTTING

There is a Dockson Better-Built Torch for all your jobs. Dockson Torches incorporate a new, longer life, better seal compound developed especially for oxy-acetylene service in both the mixer and union rings. Dockson's two-ring construction means fewer rings to replace, stronger construction, prevention of possible breakthrough.

Your DOCKSON DISTRIBUTOR—a selected specialist, stocks a complete line of Dockson products to give you fast service and personal attention. We back our distributors 100%.

WRITE FOR YOUR DISTRIBUTOR'S NAME AND COMPLETE CATALOG OF WELDING AND CUTTING EQUIPMENT.

Dockson CORPORATION

3339 WABASH • DETROIT 8, MICH.

Metal & Thermit Adds Metallurgist

James L. Oberg has joined Metal & Thermit Corp. in the capacity of technical adviser. In his new position, he will handle special assignments on metals, Thermit and electric welding processes. His headquarters will be in New York City.

Mr. Oberg has been associated with the Babcock & Wilcox Co. for the past 15 years.

National Cylinder Promotes Wedereit

Charles J. Haines, president of the National Cylinder Gas Co., Chicago, recently announced the promotion of Gene Wedereit to the post of director of advertising for NCG and its divisions and affiliates.

Mr. Wedereit has been director of advertising of the Girdler Co. and Tube Turns, Louisville, Ky., since 1943. Both companies are divisions of the National Cylinder Gas Co. He was formerly vice-president in charge of creative service for the E. F. Schmidt Co., Milwaukee.

Mr. Wedereit is past-president of the National Industrial Advertisers Association (1952–53), and is serving his second term as chairman of the board of trustees of the Industrial Advertising Research Institute, Cleveland. He is also director of the Advertising Club of Louisville, Inc.; a director and chairman of the public information committee of the Louisville Chapter of the American Red Cross, and represents his companies in the Association of National Advertisers and the American Marketing Association.

New Progressive Representative

The Progressive Welder Sales Co. nationally prominent manufacturer of resistance welding equipment announce the appointment of Welders Supply, Inc., 430 S. Industrial St., Dallas, Tex., as their representative in the northern Texas area.

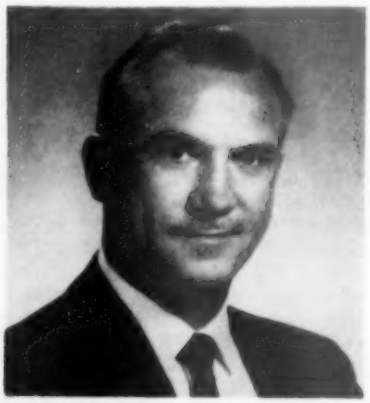
Alloy Rods Changes Field Personnel

E. R. Walsh, III, vice-president in charge of sales, announced recently the following changes in field representatives. John Fitzgerald, field representative out of the Pacific Coast sales office at El Segundo, Calif., has been transferred to the newly opened Newark, N. J., sales office and warehouse.

Richard James, III, has replaced Fitzgerald and will work from the Pacific Coast sales office. James has been the company's distributor representative in the Eastern States area for the past three years.

John Fitzgerald

J. R. Ruckman has been appointed district manager in the company's Southern and Southwestern territory. Ruckman will work with distributors in that territory.



J. R. Ruckman

CLEAN FLUX for GOOD WELDS

6 MONTH REPORT USING ARONSON-TWINNER MAGNETIC CLAMPS TO REMOVE METALLIC PARTICLES FROM SUBMERGED ARC FLUX:

BEFORE: Welds not smooth. Pinholes now and then. No apparent reason for this condition.

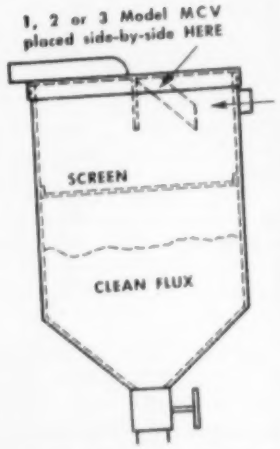
Used 50 lbs. new flux each week in effort to have clean flux.

Short in nozzle about every 3 to 4 weeks caused burn-through at nozzle tip and jamming of wire and feed.

AFTER: Smooth welds. Absolute elimination of all pinholes.

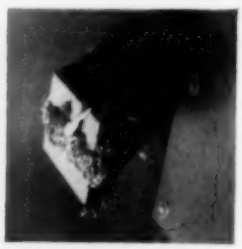
100 lb. batch of flux now lasts full month.

Have not had burn-through jam or damaged nozzle in the whole 6 months of test.



INSTALLATION requires no holes or bolts, Magnetic Clamp secures itself in place.

Wipe off Clamps each time screen is cleaned.



MCV

Write for Bulletin Showing Other Cost-Cutter Uses.

Aronson MACHINE COMPANY
ARCADE, NEW YORK

gives complete, automatic arc control

IN ANY WELDING POSITION:

...overhead
...vertical
...downhand

an exclusive feature

of the new VICKERS® *Controlarc*

magnetic amplifier-rectifier *DC Welder*

in 200, 300, 400 Ampere Models

- Easy, Clean Arc Strikes
- Hot Starts, Immediate Penetration
- Fast Arc Recovery
- No Arc "Pop Outs"
- No Current Drop-Off During Pass
- Uniform Fusion, Steady Rate of Metal Deposit
- Adaptable to Inert-Arc Applications

WRITE TODAY
for new bulletin

Territories open for qualified dealers. Write for details

VICKERS ELECTRIC DIVISION

VICKERS Inc. a unit of Sperry Rand Corporation

1853 LOCUST STREET • SAINT LOUIS 3, MISSOURI

New A. O. Smith Distributor

Economy Electric Co. of Youngstown, Ohio, has been appointed as a distributor of A. O. Smith welding products. This company has been in business for 38 years and has one of the largest motor repair shops in this area.

Flaw Location Movie

A full color and sound, 23-min 16-mm motion picture titled "Flaw Location with Dye Penetrants" has been completed by Turco Products, Inc., and is available for free showing to industrial concerns, technical groups and other interested organizations. The film, which is intended primarily for training purposes, visually demonstrates every aspect of dye penetrant inspections from laboratory theory to authentic production-line techniques actually filmed on location during mass production dye penetrant inspections.

Turco field service representatives are available in all sections of the United States to show the film. Arrangements for viewing the film or additional information may be secured by writing to Turco Products, Inc., 6135 S. Central Ave., Los Angeles 1, Calif.

GRADUATION TIME AT NEW WELDING INSTITUTE

The first group of graduates from the A. O. Smith Corp.'s Welding Institute shown with their certificates. The A. O. Smith administrative group is at the right, with John E. Conway (center) director of education and training, making the presentation

New Welding Institute Awards Certificates

The first group of customer personnel were recently awarded certificates from A. O. Smith Corp.'s Welding Institute of Milwaukee.

The Institute, founded in 1954, has three main objectives: (1) the improvement of welding quality; (2) the reduction of welding costs and manufacturing processes; (3) to make available to its customers and operating divisions the vast know-how of the welding research organization.

A. O. Smith Corp. feels that these three objectives make the Welding Institute a highly important activity in its in-plant and customer relations programs.

A number of welding engineers and customer representatives are enrolled by A. O. Smith in a two-week course in advanced welding techniques and processes. This course includes advanced work in manual, automatic and semiautomatic welding procedures.

MORE PRODUCTION LESS DOWNTIME

• Reline TRUCK BOTTOMS, SKIPS, CHUTES and HOPPERS with . . .

MANGANAL

Trade Mark Reg. U. S. Pat. Off.

11%-13½% MANGANESE-NICKEL STEEL HOT ROLLED PLATES

WRITE for your copy of detailed specifications on Manganal Hot Rolled Plates.

• Reduce impact and abrasive wear. Work-harden, too!

• Can be flame cut, welded, formed, sheared and punched.

STULZ-SICKLES CO.

SOLE PRODUCERS 92 N. J. RAILROAD AVE. NEWARK, N. J.

NEAREST DISTRIBUTOR UPON REQUEST

Schneller Promoted

A. R. Schneller, who has been Pacific Coast sales manager for the Welding Products Division of A. O. Smith Corp. in the past two years, moves to the new position of Eastern regional sales manager for the Division, it is announced by R. W. Raney, general sales manager. The corporation operates its eastern electrode manufacturing plant at Leola, Pa. Before his activity on the West Coast Mr. Schneller was in charge of welding sales in Wisconsin.

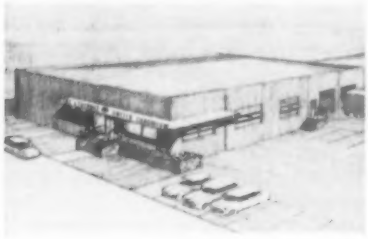
McMillin Made Vice-President

E. J. Cosford, president and managing director of Canadian Car & Foundry Co., Ltd., following a meeting of the board of directors, announced the appointment of G. L. McMillin, B.S.-C.E., as vice-president, Steel Foundry. Mr. McMillin was formerly assistant vice-president, Steel Foundry.

He is a member of the American Welding Society.

Metal & Thermit Erecting New Building

Metal & Thermit Corp. has announced that it is establishing new sales headquarters for the Pacific Coast region in the Los Angeles area. The company expected to move its western headquarters, toward the end of July, into a new warehouse and office building now under construction at 1926 Maple Ave., El Segundo, Calif.



The new building will provide warehousing facilities for the products of all Metal & Thermit divisions: welding materials, industrial chemicals, ceramic materials and the plating and coating materials of M & T's United Chromium Division.

The office space will house the Pacific Coast Regional sales headquarters personnel, under the direction of E. E. Anderson, vice-president, general manager for all West Coast operations.

The Los Angeles facility will be in charge of R. E. Collins, who will directly supervise the operation of the warehouse and will be responsible for chemical, ceramic and United Chromium Division sales. The new location will also be headquarters for welding sales personnel for the West Coast region.

The building, which will contain 11,000 sq ft of floor area, is of "tilt-up" concrete construction. The walls are formed from sectional slabs poured in horizontal forms, then erected into position. The facilities will include a paved parking lot, a railroad siding and ample truck loading and unloading docks for highway transport.

High Frequency Resistance Welding Demonstrated

High frequency resistance welding was demonstrated during the last three weeks in May as the New Rochelle Tool Corp. of New Rochelle, N. Y., exhibited its new high frequency resistance tube welding technique as applied to an Abbey Etna tube mill at the latter company's plant in Toledo, Ohio.

Over 200 representatives of many of the largest metal fabricating companies in the United States witnessed what is claimed to be the most flexible and versatile welding tool yet applied to the production of continuous seams. In the new process demonstrated, the unique effects of high frequency reactance are invoked to direct and pinpoint the current into the edges of the metal being joined, resulting in greater energy concentration than can be secured by any other heating means.

Untreated hot- and cold-rolled steel, stainless steel, copper, aluminum and brass were among the metals welded.

Arcos Promotes Light

John K. Light has been appointed to the newly created position of assistant sales manager by the Arcos Corp., Philadelphia, manufacturer of welding rods and electrodes. His appointment took effect June 1st.

James A. Brickett, Jr., former Arcos salesman in the New England area, succeeds Light as district sales manager. He will maintain headquarters in Boston.

Light has been with Arcos since 1944. He was assistant to the sales manager for one year, a field engineer in the research department for a year, and New England sales manager for the past nine years.

Before joining Arcos, he was assistant superintendent of welding and fabricating for three years at the L. R. Hilyard Co., Norristown, Pa., and

John K. Light

served eight years with John Wood Manufacturing Co., Conshohocken, Pa. in the engineering and design of welded vessels and fabricated weldments.

For many years, Light has been active in the Philadelphia, Hartford, Conn., and Boston Sections of the American Welding Society. He was acting vice-president of the Northeast District No. 1 from 1953 to 1954, and before that served as chairman, vice-chairman and program chairman of the Hartford Section.

AT THE FRONTIERS OF PROGRESS YOU'LL FIND

AN AIR REDUCTION PRODUCT

FOR WELDING AND CUTTING...

IN THE RED DRUM

HIGHEST QUALITY

DUST-FREE

NATIONAL CARBIDE

Write for the name and address of the NATIONAL CARBIDE supplier nearest you.

National Carbide Company

GENERAL OFFICES: 60 EAST 42ND STREET, NEW YORK 17, N. Y.

A DIVISION OF AIR REDUCTION COMPANY, INCORPORATED

PERSONNEL

Broden Elected Vice-President

Edwin R. Broden was selected executive vice-president, of SKF Industries, Inc., at a recent meeting of the board of directors according to an announcement by Richard H. DeMott, board chairman and president of the Philadelphia ball and roller bearing firm.

Broden was formerly executive vice-president and a director of the Carborundum Co., Niagara Falls, N. Y., which he joined in 1944 as vice-president in charge of operations. Previously, he was a division manager of the Blaw-Knox Co., Pittsburgh, Pa., and director of industrial activities of the United Natural Gas Co., Oil City, Pa.

He is a member of the AMERICAN WELDING SOCIETY, American Management Assn., American Ordnance Assn., American Society for Testing Materials, American Iron and Steel Inst., ASME, SAE and the Engineers Society of Western Pennsylvania.

Higgins Retires

Nathan B. Higgins, president of Safe Harbor Water Power Corp., retired on May 31st after 41 years of service in the electric industry.

A graduate of Pennsylvania State College with a B.S. degree in Civil Engineering, Mr. Higgins' early experience was as a structural draftsman with the Cambria Steel Co. and the Penn Bridge Co. In 1910, he moved to Baltimore, where he became associated with the Baltimore Bridge Co. as a structural estimator. He later spent several years with the Western Maryland Railway Co. as designer-erector of bridges, buildings, piers and terminals.

In 1914, he joined the Pennsylvania Water & Power Co. as chief draftsman in its Baltimore office. Successively, he was its assistant chief engineer, chief engineer and advisory engineer. When the Safe Harbor Water Power Corp. was formed, Mr. Higgins became its assistant chief engineer and, later, chief engineer. In 1942, he was elected president and a director of the Safe Harbor Corp., which position he held until retirement.

Mr. Higgins is a Fellow of the American Institute of Electrical Engineers and the American Society of Mechanical Engineers; a member of the AMERICAN WELDING SOCIETY, American Society of Civil Engineers, American Concrete Institute and the Engineers Club of Baltimore. He is a Registered Professional Engineer in New York, Pennsylvania and Maryland.

Powell Completes Thirty Years of Service

Elmer E. Powell, head of the Pittsburgh office of Esso Research and Engineering Co., has reached 30 years' service with the company.

Mr. Powell began his long service with the company in 1925 as an inspector in the old General Engineering Department of Standard Oil Co. (N. J.). He was transferred to Esso Research and Engineering in 1928, and was named to head that company's Pittsburgh office in 1937.

Following an assignment in the mid-forties at the Esso Engineering office in Linden, N. J., Mr. Powell was sent to Antwerp, Belgium, in 1950 on a project dealing with materials procurement and inspection methods and procedures. The Esso engineer has been back at the Pittsburgh office since 1953.

A veteran of World War I, Mr. Powell studied mechanical engineering at Carnegie Institute of Technology.

An active member in the American Legion, the Masons and the Kiwanis Club, he is also a member of the AMERICAN WELDING SOCIETY, the American Petroleum Institute and the American Society of Testing Materials.

Clason Joins Adams

Clyde B. Clason, formerly managing editor of *Welding Engineer*, Chicago, has joined the staff of Adams Associates, Inc. (successors to The W. H. Long Co., Inc.), York, Pa., advertising agency. He will be director of a public relations and publicity service for the firm's clients.

A graduate of the University of Denver in 1925, Mr. Clason has been engaged in business journalism most of his life. In 1942, he resigned as managing editor of *Electrical Dealer*, Chicago, in order to join Welding Engineer Publishing Co., Inc. He was made managing editor of *Welding Engineer* when this paper was purchased by McGraw-Hill Publishing Co., Inc., in 1945.

Buechler Named Chief Engineer

L. W. Buechler has been named chief engineer for Vickers Electric Division, Vickers Inc., St. Louis, Mo. Mr. Buechler was formerly manager of Control Product Sales for the Division.

Cuntz Promoted

William C. Cuntz has been named assistant manager of sales, Welding Department, Metal & Thermit Corp., New York, N. Y. He will assist Robert T. Brown, manager, in sales of Thermit welding materials and equipment. He joined Metal & Thermit in 1936 and has been assistant in rail welding research and district manager at Pittsburgh, Pa. Mr. Cuntz is a graduate of the Colorado School of Mines and holds the degree of Bachelor of Science in Metallurgical Engineering from Lehigh University.

A. J. Smith Is Promoted

Albert J. Smith has been appointed sales manager, Electrode Division, of the McKay Co., it was announced by Fred A. Kaufman, vice-president. Mr. Smith will make his headquarters at the company's offices in Pittsburgh, Pa.

Mr. Smith has a broad background in the field of welding. He served as a metallurgical engineer in the Technical Service Division of the company, and prior to his present appointment was assistant sales manager of the Electrode Division.

Albert J. Smith

BULLETIN SERIES

Requests for single copies should be sent to the
AMERICAN WELDING SOCIETY, *29 W. 39th St., New York 18, N. Y.*

Requests for bulk lots ten or more, should be sent to the
WELDING RESEARCH COUNCIL, *29 W. 39th St., New York 18, N. Y.*

No. 1 **Steel Compositions and Specifications,** *by Charles M. Parker, March 1949. $0.50.*

No. 2 **The Nature of the Arc,** *by J. D. Cobine, April 1949. $0.50.*

No. 3 **Burn-Off Characteristics of Steel Welding Electrodes,** *by D. C. Martin, P. J. Rieppel and C. B. Voldrich, May 1949. $0.50.*

No. 4 **Testing Pressure Vessels,** *by F. G. Tatnall;* **Effect of Welding on Pressure Vessel Steels,** *by A. F. Scotchbrook, L. Eriv, R. D. Stout and B. G. Johnston, February 1950. $0.50.*

No. 5 **How Plastic Deformation Influences Design and Forming of Metal Parts,** *by John R. Low, Jr.;* **Brittle Fracture in Mild Steel,** *by J. S. Hoggart, May 1950. $1.00.*

No. 6 **Stress Corrosion Cracking of Stainless Steels,** *by Helmer Nathorst; Part I—***Practice Experiences;** *Part II—***An Investigation of the Suitability of the U-bend Specimen,** *October 1950. $1.00.*

No. 7 **Instrumentation for the Evaluation of the Stability of the Welding Arc,** *by L. P. Winsor, L. McDonald Schetky and Robert A. Wyant, November 1950. $1.00.*

No. 8 **Tests of Columns under Combined Thrust and Moment,** *by Lynn S. Beedle, Joseph A. Ready and Bruce G. Johnston, December 1950. $1.00.*

No. 9 **Copper in Stainless Steels,** *by Helmut Thielsch, August 1951. $1.00.*

No. 10 **Thermal Fatigue and Thermal Shock,** *by Helmut Thielsch, April 1952. $1.00.*

No. 11 **Investigations of Effect of Fabrication Operations Upon Pressure Vessel Steels,** *by S. S. Tör and Robert D. Stout, May 1952. $1.00.*

No. 12 **An Analytical Study of Aluminum Welding,** *by C. O. Smith, E. R. Funk and H. Udin, June 1952. $1.00.*

No. 13 **A New High-Yield Strength Alloy Steel for Welded Structures,** *by L. C. Bibber, J. M. Hodge, R. C. Allman and W. D. Doty, July 1952. $1.00.*

No. 14 **Welding Processes and Procedures Employed in Joining Stainless Steels,** *by Helmut Thielsch, September 1952. $2.00.*

No. 15 **Slag-Metal Interaction in Arc Welding,** *by Nils Christensen and John Chipman, January 1953. $1.00.*

No. 16 **Ship Structure Research, Part I—The Third Technical Report of the Ship Structure Committee; Part II—Research Under the Ship Structure Committee,** *by Capt. E. A. Wright, Finn Jonassen and H. G. Acker, November 1953. $2.00.*

No. 17 **A Critical Survey of Brittle Failure in Carbon Steel Structure Other Than Ships,** *by M. E. Shank, January 1954. $2.00.*

No. 18 **Testing of Stainless-Steel Weldments,** *by Helmut Thielsch, September 1954. $1.00.*

No. 19 **Review of Welded Ship Failures,** *by Harold G. Acker, November 1954. $1.00.*

No. 20 **High-Strength, Low-Alloy Steels; Analytical Chemistry Fosters Progress in Steelmaking; Steel Quality;** *by Charles M. Parker, January 1955. $1.00.*

No. 21 **Coating Moisture Investigations of Austenitic Electrodes of the Modified 18–8 Type,** *by K. P. Johannes, D. C. Smith and W. G. Rinehart, February 1955. $1.00.*

No. 22 **Welded Tee Connections,** *by A. G. Barkow and R. A. Huseby, May 1955. $1.00.*

No. 23 **Cracking of Simple Structural Geometries,** *by S. T. Carpenter and R. F. Linsenmeyer, July 1955. $1.00.*

He holds a degree in Metallurgical Engineering from the University of Pittsburgh and is an active member of the AMERICAN WELDING SOCIETY, the American Society for Metals and other industry organizations.

Bellware Relocates

M. D. Bellware has joined The International Nickel Co., Inc., as a member of the welding group of the Development and Research Division's Technical Service Section, according to an announcement by O. B. J. Fraser, assistant manager of the division. Mr. Bellware will devote most of his time to the iron base alloys, particularly the austenitic stainless steels.

M. D. Bellware

Mr. Bellware became associated with the Westinghouse Electric Corp. as a member of the staff of its manufacturing engineering laboratory at East Pittsburgh in 1951 after graduating from Ohio State University with the degree of Bachelor in Welding Engineering. From 1952 until his present appointment, he served with Kaighin and Hughes, Inc., and The Rust Engineering Co., as welding engineer on U. S. Atomic Energy Commission projects at Oak Ridge, Tenn.

He is a member of the AMERICAN WELDING SOCIETY and the American Society for Metals.

Sutton Joins INCO

C. Roger Sutton, senior metallurgist at the Argonne National Laboratory of the U. S. Atomic Energy Commission for the past five years, has joined the Development and Research Division of The International Nickel Co., Inc., as a member of the Stainless Steel and Heat Resistant Alloys Section, according to an announcement by F. L. LaQue, vice-president and manager of the division.

C. Roger Sutton

Mr. Sutton is a graduate of the University of Detroit, where he received the degree of Bachelor of Chemical Engineering in 1927 and the Master of Science degree in 1928.

Prior to his appointment as senior metallurgist at the Argonne National Laboratory in 1950, Mr. Sutton held responsible positions with several organizations.

Mr. Sutton is a member of the AMERICAN WELDING SOCIETY, American Society for Metals, American Institute of Mining and Metallurgical Engineers, Franklin Institute, Scientific Research Society and the American Institute of Chemical Engineers.

Petryck Transfers

Leon M. Petryck has joined the Development and Research Division of the International Nickel Co., Inc., as a research metallurgist in the Welding Section of the Research Laboratory at Bayonne, N. J., according to an announcement by Dr. W. A. Wesley, manager of the laboratory. The Welding Section is being enlarged in order to expand research in this important field.

Leon M. Petryck

Mr. Petryck is a graduate of Rensselaer Polytechnic Institute, Troy, N. Y., holding the degree of Bachelor of Science in Metallurgical Engineering. Before his present appointment he was associated in various welding engineering capacities with Carrier Corp., Syracuse, N. Y., Pullman-Standard Car Mfg. Co., Chicago, American Locomotive Co., Schenectady, N. Y., and Cheney Hammer Corp., Little Falls, N. Y.

During World War II, Mr. Petryck served as a shipfitter in the United States Navy and attended the Navy Fleet Welding School at Norfolk, Va. He is a member of the AMERICAN WELDING SOCIETY.

WELDING SALES ENGINEERS

Established, progressive company with diversified interests in welding, metals, chemicals, and ceramics industries is expanding its nation-wide welding sales division by the addition of allied products. Requires welding sales engineers with college education or equivalent to sell complete line of welding products including allied inspection equipment. Experience in welding, fabrication or constuction fields preferred. Sales experience desirable but not a requisite. Age 26 minimum. Excellent opportunity for advancement. State education, experience and salary expected. V-324

HOBART ELECTRIC WELDERS

BEST MADE

(Electric Motor Driven)

GOV'T. SURPLUS

200 Amp. welders.
Guaranteed like-new condition.

$195.00 EACH

300 Amp. slightly higher.
3 phase 220–440 volts. Will ship open account to accredited firms. Also a few Lincoln and Westinghouse Welders.

ORDER YOURS TODAY!

CALL, WIRE OR WRITE

FULTON AUTO EXCHANGE

We carry a complete line of Army equipment, trucks and parts.
2235 Stewart Ave., S. W., Atlanta, Ga.
Telephone FAirfax 8606

EMPLOYMENT SERVICE BULLETIN

Positions Vacant

V-324. Welding Sales Engineers. Established, progressive company with diversified interests in welding, metals, chemicals, and ceramics industries is expanding its nation-wide welding sales division by the addition of allied products. Requires welding sales engineers with college education or equivalent to sell complete line of welding products including allied inspection equipment. Experience in welding, fabrication or construction fields preferred. Sales experience desirable but not a requisite. Age 26 minimum. Excellent opportunity for advancement. State education, experience and salary expected.

Welding Development Engineers. Old established company located in Western New York is expanding operations and requires services of additional Welding Engineers. Openings exist for both experienced engineers and young graduates. Write fully giving personal data, experience, references and salary expected.

Personnel Manager, ALCO Products, Inc., formerly American Locomotive Co., Dunkirk, N. Y.

Services Available

A-676. Export Sales Manager. Specialist in welding equipment. Electric, oxy-acetylene. Unusually successful export sales record. Traveled overseas. Wide foreign contacts. Complete knowledge distributor-dealer patterns. Broad background all phases foreign trade. Available to establish and operate export department for manufacturer or group of non-competitive manufacturers.

A-677. Salesman and sales engineer open for sales position. Practical man with two years technical training. Twenty-three years experience in welding industry. Fully versed in oxy-acetylene and electric welding. Also experienced in industrial sales, distributor setups and direct selling. Located in Chicago.

A-678. Desire position in the welding engineering or supervision field. Married, age 39. Past ten years as Welding Foreman. Previous five years as Welding Instructor, Welding Specialist and Welding Engineer, also 2½ years of welding major in college. Seasoned in all phases of welding, production control, time study, estimating, development of procedures and processes, manufacturing methods, personal relations. Desires location Western States area, will consider other locations. Full résumé of experience and personal background available.

.....for Better Welding

USE THE TONG TEST AC-DC AMMETER

Machine settings alone cannot control welding quality! Measure actual welding current instantly, accurately and safely by simply clamping a Tong Test Ammeter around the electrode cable. Only Columbia Tong Test measures both AC and DC. Interchangeable ranges available up to 1000 amperes.

Prevent costly defects—increase welding production—maintain valuable equipment—with low cost Tong Test Ammeter. Get the facts today!

Write for 8-Page Catalog WJ-400

COLUMBIA

6514-CE

COLUMBIA ELECTRIC MFG. CO.
4513 Hamilton Avenue • Cleveland 14, Ohio

WELDING ENGINEER

Fast moving R & D company—with altogether new and unique welding process—has outstanding opportunity for aggressive individual meeting the following requirements:

- Welding engineer with mechanical design background
- Been successful in development of electronical welding equipment
- Electronics exposure very desirable
- PhD or equivalent. Age 34-42

Defense Department and AEC clearance will be required. Salary commensurate with ability and experience. Box V-325

Get the BEST for LESS
Get
"ANTI-BORAX" FLUXES
Fully Guaranteed
SAFE—NON-TOXIC

No. 1 Cast Iron Welding Flux
No. 2 Brazing Flux
No. 4 "Braz-Cast" Flux for bronze welding cast iron
No. 8 "ABC" Sheet Aluminum Flux
No. 16 Silver Solder Paste Flux.

Send for complete Folder

Mfg. by
ANTI-BORAX COMPOUND CO. INC.
Fort Wayne 9, Indiana

New AC/DC Welder
Lowest in Cost...
Best in Performance!

The Westinghouse RMC welder furnishes 25 to 250 amps a-c or 20 to 200 amps d-c from a single-phase, 230-volt, 60-cycle outlet.

The RMC offers you *NEW* manufacturing freedoms:

- Continuous current range for a-c or d-c
- Overload protection
- Needs only 47 primary amps
- Very portable...only 200 pounds
- It will burn any type electrode

RMC is your answer for fabrication where one welder is doing a-c and d-c welding.

Get the facts now. Write WESTINGHOUSE ELECTRIC CORPORATION, WELDING DEPT., Box 868, Pittsburgh 30, Pennsylvania.
J-21916

YOU CAN BE SURE...IF IT'S Westinghouse

NEW PRODUCTS

Temperature Indicators

Tempil® Corp., 132 W. 22nd St., New York 11, N. Y., announces that its products are now being labeled with both the Fahrenheit and Centigrade temperature ratings.

This company has also prepared a table of Fahrenheit and Centigrade equivalents for which Tempil® products are manufactured. Copies of these are available to our readers, gratis. Write directly to the company.

Welding Head

Raytheon Product Data Sheet, PD 2-201, describes the Raytheon Model J Welding Head, a compact precision welding unit for small parts and subassemblies. According to the manufacturer, it produces strong clean welds at high speeds with a minimum of operator fatigue. It requires little bench area and is relatively trouble free with a minimum of maintenance. It is claimed to be particularly applicable for miniature and subminiature assemblies.

For complete information, write to Equipment Marketing Division, Raytheon Manufacturing Co., Waltham, Mass.

Atlas Dual-Case

The Atlas "dual-case," manufactured by Atlas Welding Accessories Co., 707 E. Lewiston, Ferndale 20, Mich., is now being sold nationally through welding supply dealers.

This case is divided into two separate compartments for welding rods and chipping tool. It fastens on the belt and is designed to enable the wearer to reach for and extract either rod or hammer without looking.

Generator-Type Welders

A new line of gasoline engine driven generator-type welders have been announced by the Westinghouse Electric Corp. Available in current ranges of 30 to 350 amp, ac or dc, the new welders are compact, completely self powered and may be equipped with optional gear.

One d-c model is a dual-purpose unit which not only handles all types of d-c welding but can also be converted into an a-c power plant by a conversion switch. The a-c model also has a 110-v d-c outlet for operating universal drills and lights. Another model is equipped with high frequency so that it can be used for inert-gas tungsten-arc welding. All the models have infinite current adjustment steps.

The gasoline engine is an air-cooled, four-cylinder, 20-hp Onan model CW. It has electric starting and an internal fly-ball governor with a variable-speed control attachment.

For further information on this new line of welders, write Westinghouse Electric Corp., PO Box 2099, Pittsburgh 30, Pa.

Surfacing Electrode

The new Mir-O-Col #13-S developed by Mir-O-Col Alloy of Los Angeles, Calif., is designed for high-speed rate of deposit on heavy-duty equipment such as grader blades, shovel bucket lips and similar hard-working equipment.

A self-hardening rod designed for electric welding only, Mir-O-Col #13-S is highly alloyed to produce a tough, shatterproof deposit. Rockwell C scale 50–55. The rod can be applied with a-c or d-c, reverse or straight polarity.

Mir-O-Col #13-S is available in a full range of sizes. Free samples of the electrode, along with descriptive literature, are available on request to Mir-O-Col Alloy Co., Inc., 312 N. Avenue 21, Los Angeles 31, Calif.

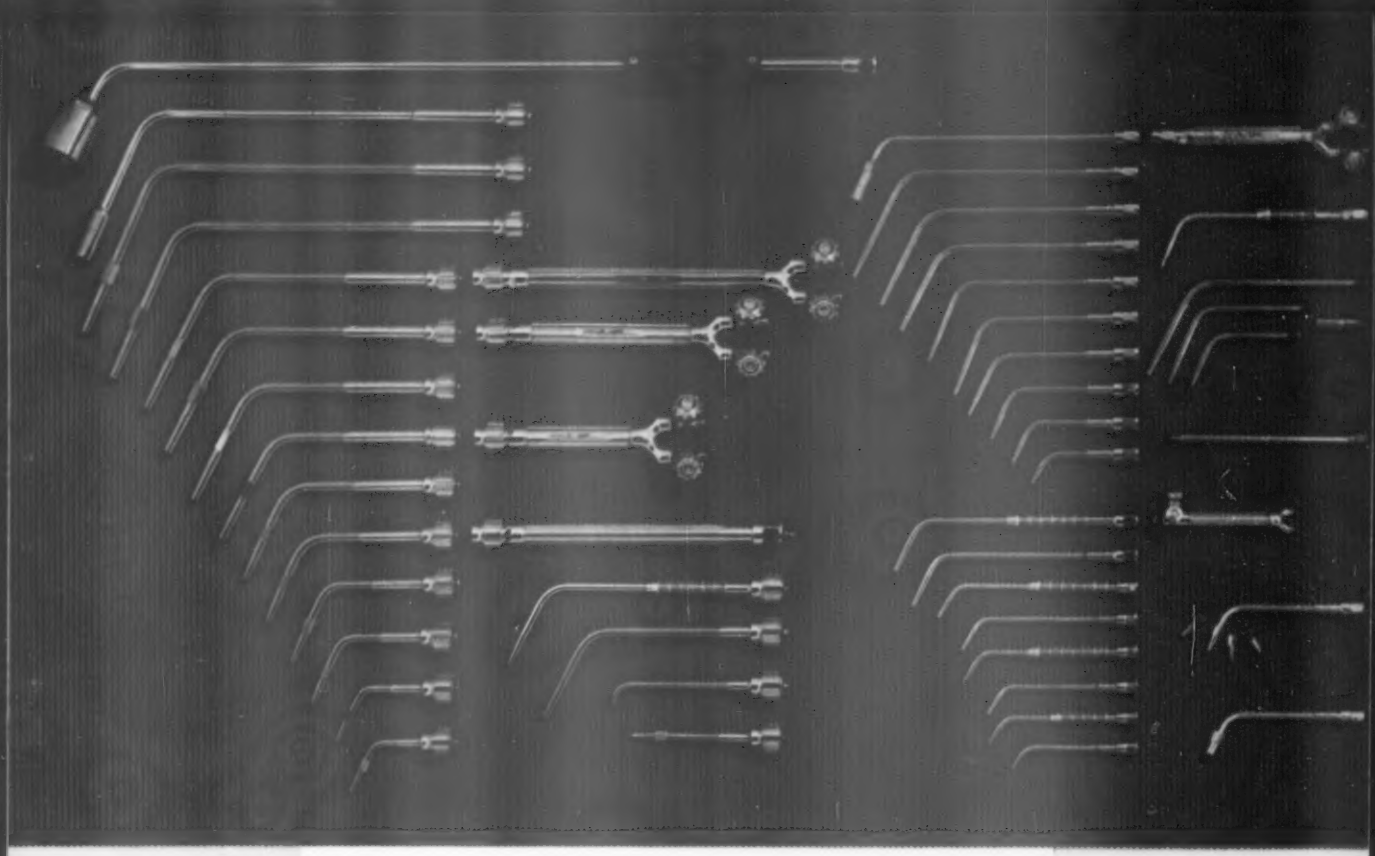
Hard-Facing Electrode

A new low-cost, low-hydrogen hard-facing alloy, known as Colmonoy No. 2, for application to working surfaces of construction, mining and aggregate handling machinery and similar heavy-duty equipment where impact and wear resistance are required, is now available from Wall Colmonoy Corp., 19345 John R. St., Detroit C, Mich. For additional information, write directly to manufacturer.

Electric Metallizer

Arnold Serton, Inc., announces the availability of a new electric metallizing gun. According to the manufacturer, this unit works with an air pressure of about 100 psi without relief valve and gives high pressure speed. It has a melting capacity of 55 lb of zinc per hour with a wire of about $^1/_{16}$ in. and, reportedly, can easily be changed for heavier wire if desired, thus giving about 88 lb zinc per hour.

Complete information may be had by writing to Arnold Serton, Inc., 10 Rockefeller Plaza, New York 20, N. Y.



Fit the flame to the job with

VICTOR nozzles and tips

Why lose time and waste gas with a "misfit" flame? Start *right* with a Victor torch, match the flame to *any* job with Victor interchangeable nozzles and tips. Victor torches that "grow with the job" cost no more, pay you plenty in faster, better work. See them at your Victor dealer's today, or write *now* for catalog.

VICTOR for welding

VICTOR EQUIPMENT COMPANY

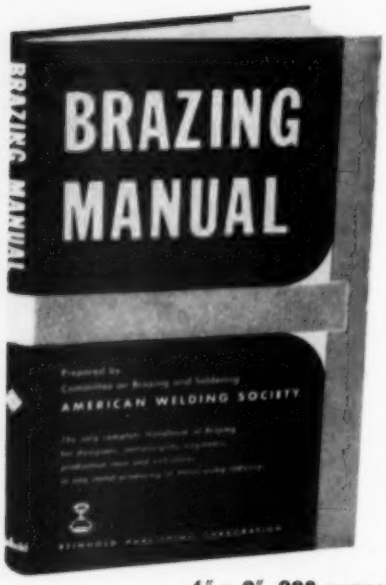
Mfrs. of welding & cutting equipment; hardfacing rods, blasting nozzles; cobalt & tungsten castings; straightline and shape cutting machines.

844 Folsom St.
San Francisco 7

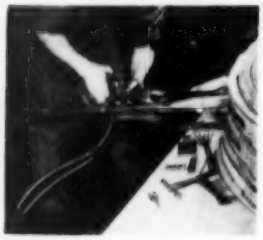
3821 Santa Fe Avenue
Los Angeles 58

Everything on Brazing—in the First Complete Handbook!

BRAZING MANUAL



6″ x 9″, 208 pages
Price to AWS members, $3.80
Price to non-members, $4.75



Covers every aspect of torch, furnace, induction, resistance, dip, block, flow and step brazing methods

Expert, up-to-the-minute information in these 23 important chapters . . .

1 Brazing Processes, Equipment and Procedures
2 Properties of Base Metals
3 Brazing Filler Metals
4 Fluxes and Atmospheres
5 Drafting Room Practices
6 Joint Design
7 Precleaning and Surface Preparation
8 Assembly
9 Technique of Brazing
10 Postbraze Operations
11 Inspection
12 Aluminum and Aluminum Alloys
13 Magnesium
14 Copper and Copper Alloys
15 Low-Carbon and Low-Alloy Steels
16 Stainless Steels
17 High-Carbon and High-Speed Tool Steels
18 Cast Iron
19 Heat-Resistant Alloys
20 Nickel and High-Nickel Alloys
21 Precious Metal Contacts
22 Other Metals
23 Safety and Health Protection
APPENDIX: Properties of Brazeable Metals and Alloys

Prepared by the
Committee on Brazing and Soldering

AMERICAN WELDING SOCIETY

Here in one handy volume are the full, up-to-the-minute details of all brazing processes now used in the automotive, aircraft, refrigeration, electronics and other mass-production metal industries!

Answers Your Every Brazing Problem!

Written by the country's top experts on all aspects of brazing, and replete with charts, tables and illustrations, the *Manual* brings you just the kind of practical information you need to answer every type of brazing problem. Separate chapters describe the principles, equipment and procedures involved in the eight brazing processes; each operation from precleaning and surface preparation to postbraze cleaning and inspection; and the techniques of brazing aluminum, magnesium, copper, steels, iron, nickel, and many other metals.

Special attention is given to joint design, to the properties of base and filler metals, to fluxes and atmospheres, and to the causes of defects together with corrective measures. Also included is a valuable quick-reference table showing metals in similar and dissimilar combinations, and filler metals to be used.

The Only Book of Its Kind!

With the appearance of this new Handbook, another milestone is marked in the history of brazing. For now, brazing takes its place with other branches of engineering which, for many years, have had handbooks published in their respective fields.

Nowhere else could you find such a *complete* source of reliable, up-to-date brazing information! Designers, metallurgists, engineers, production men, supervisors, executives—*anyone* concerned with non-ferrous metals or with ferrous to non-ferrous joining—will welcome this vast range of valuable design, process and finishing data. Users of brazed products will also find the book of immense help in preparing specifications and in determining proper inspection methods.

From the list of chapter headings, you'll get some idea of the Manual's exceptional range and scope. Only the book itself, however, will show you how capably and thoroughly every single topic is covered. Don't fail to order *your* copy now!

USE THIS COUPON TO ORDER NOW

AMERICAN WELDING SOCIETY
33 West 39th Street, New York 18, N. Y.

Please rush me a copy of BRAZING MANUAL.

☐ I am an AWS member—bill me for $3.80
☐ I am not an AWS member—bill me for $4.75

NAME .....

ADDRESS .....

CITY & ZONE ..... STATE .....

Electrode for Cast Iron

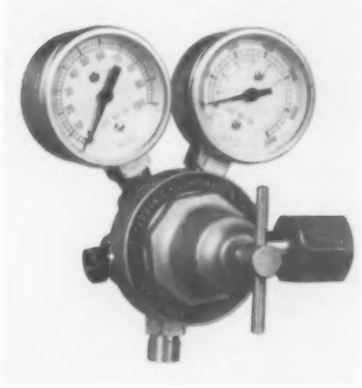
A new electrode, Pacific Nickel Cast, has been placed on the market by Pacific Welding Alloys of Los Angeles, Calif. This electrode is especially recommended by the manufacturer for the repair welding of cast iron. The weld itself is easily machinable under all conditions of deposition.

Pacific Nickel Casts can be operated from ac or dc. However, reverse polarity is recommended. At all times the welding current should be as low as possible.

Descriptive literature, price lists and samples of Pacific Nickel Cast are available on request. Write to Pacific Welding Alloys Manufacturing Co., 310 N. Avenue 21, Los Angeles 31, Calif.

Pressure Regulators

The Industrial Gas Division of the Liquid Carbonic Corp. has announced the availabliity of its new R-90 oxygen and acetylene regulators.

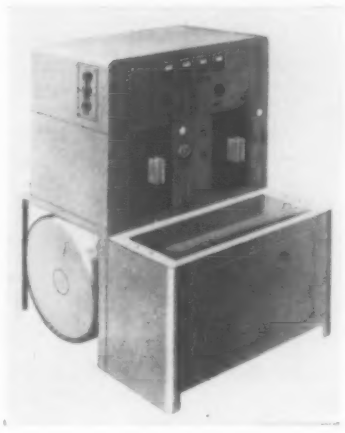


One of the outstanding features is a stable delivery of gas pressure regardless of pressure changes in the gas cylinder. While having all the features of the standard two-stage regulator, the R-90 has been reduced in size to where it weighs two-thirds less than a two stage and one-third less than a conventional single-stage regulator.

For further information on the R-90 Regulator write to: The Liquid Carbonic Corp., Industrial Gas Division, 3100 S. Kedzie Ave., Chicago 23, Ill.

30-Kw Induction Heater

A new 30-kw induction heater, either totally enclosed water-cooled, or open air-cooled, is available from the Westinghouse Electric Corp. The 30-kw induction heater is a "building block" unit that includes all elements needed for induction heating. Coils for the specific applications can conveniently and easily be added.



According to the manufacturer, the flexibility of this unit makes it ideal for hardening and heat-treating operations, metal-joining, hot-heading and forging.

For further information, write Westinghouse Electric Corp., PO Box 2099, Pittsburgh 30, Pa.

Vacuum Brazing of Titanium

The development of a new titanium brazing process which requires lower-than-normal brazing temperatures has been announced by the Stainless Processing Division of Wall Colmonoy Corp., 19345 John R St., Detroit 3, Mich. Reportedly, the process can be used with silver or silver manganese brazing alloy to fabricate an all-titanium alloy assembly or to join titanium to stainless steel or other alloys. It is applicable to assemblies of any size.

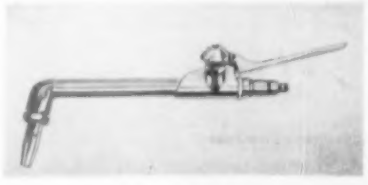
The new method is said to require no fluxes and permits the simultaneous performance of multiple brazing operations. In nature, the process is a form of vacuum brazing. Distortion does not take place because the temperatures used are below the normal brazing temperature. The new process avoids embrittlement and difficulties generally associated with high-temperature brazing of titanium.

According to the Wall-Colmonoy Corp., the wetting and flow characteristics of the process are of such a quality as to insure complete brazing of all joints, regardless of contour or position. This permits the brazing of complicated shapes and of parts in which the titanium components have been assembled prior to the application of the brazing alloy. The process, therefore, can be applied to brazing such items as titanium alloy turbine blades and honeycomb sandwich sections (see accompanying photo) where complete brazing of the upper joints is generally difficult to achieve.

Welding Torch and Cutting Attachment

A new medium-pressure oxy-acetylene blowpipe, the Oxweld W-45, has been introduced by Linde Air Products Co., a division of Union Carbide and Carbon Corp., 30 E. 42nd St., New York 17, N. Y. The W-45, with 18 welding head sizes, 8 multiflame heating heads, and 8 extensions, offers the greatest welding and heating range (2 through 300 cfh) ever available in a single hand-welding blowpipe.

The Oxweld CW-45 Cutting Attachment, designed for use with the new Oxweld W-45 Blowpipe, has been introduced by Linde Air Products Co. Capable of cutting steel 8 in. thick, the CW-45 Cutting Attachment operates on acetylene pressure of only 5 psi, a distinct advantage when cutting must be done at the extremes of lengthy acetylene supply lines.



The new torch and new cutting attachment are intended for use in contract welding shops, manufacturing plants, shipyards, railroads, steel fabricating and maintenance shops.

For further information, write directly to Linde Air Products at the above address.

Portable Fillerarc Unit

Machinery and Welder Corp., 1324 W. Fulton St., Chicago 7, Ill., in order to satisfy the needs of its customers, has found it necessary to build a cart to make the Fillerarc unit completely portable.

In order to make the component units of a Fillerarc welder portable, the weld-

ing generator and a 40-gal water circulating system are mounted on the platform of the cart. The water circulating system is provided with a motor-driven geared pump for the circulation of the water and has been found adequate to properly cool the Fillerarc gun. The wire drive unit is mounted on a table which is free to swivel so that this unit will follow the operator and thus eliminate kinking of cables, Fillerwire tube and hose to the Fillerarc gun. Space is provided at the rear of the cart for two bottles of gas.

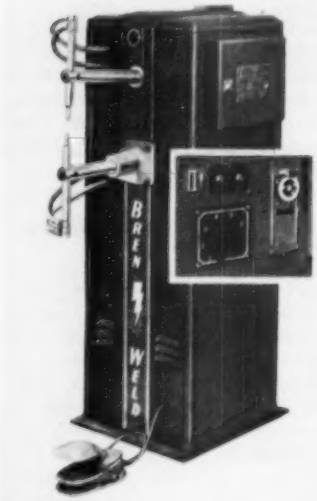
Cart is made of heavy steel plate and has four 8-in. diameter wheels with 2-in. diameter tires. Front wheels are of swivel type to provide easy maneuverability.

For additional information write to Machinery and Welder Corp. at above address.

Spot Welder

An economy-priced 10-kva, air-operated, fully automatic spot welder is now available, it was announced by the Kasson Die & Motor Corp.

Called the BREN/WELD Sp-100,



this low-cost spot welder is claimed to be the first unit of its type to feature an efficiency-increasing toroidal transformer. It welds up to two pieces of $^1/_8$-in. steel.

Details may be had by writing to the Kasson Die & Motor Corp., 32-14 Northern Blvd., Long Island City 1, N. Y.

Temperature-Sensitive Paint

The Tempil° Corp. announces the availability of their Temp-Alarm° GA-1 temperature-sensitive paint which at 400° F undergoes a dramatic color change from the original mustard yellow to maroon in 5 min.

Temp-Alarm° GA-1 is made with a silicone resin base for high-temperature service. The scheduled color transformation will develop more slowly at lower temperatures, but no permanent color change will take place below 375° F.

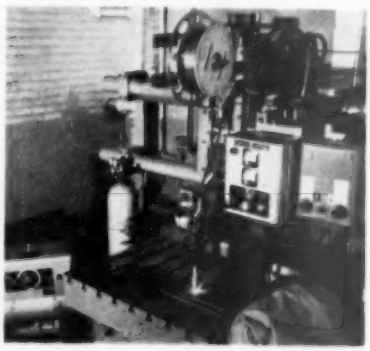
A leaflet describing Temp-Alarm° GA-1 and a 4-oz sample of Temp-Alarm° GA-1 are available, without charge, to JOURNAL readers whose request is made on their business letterhead directly to Tempil° Corp., 132 W. 22nd St., New York 11, N. Y.

CO_2 Automatic Welding Equipment

Complete new automatic, consumable-electrode welding equipment that is especially adapted for use with low-cost carbon dioxide shielding gas has been announced by Douglas A. Hopper, general manager of the General Electric Co.'s Welding Department at York, Pa.

This G-E Fillerarc equipment includes wire feeder, torch, control panel, reel mount and motor-generator unit. It employs extremely high wire speeds (up to 1000 ipm) and very short arc lengths to produce a deeply penetrating arc with a minimum of spatter.

A single generator dial allows choice of desired arc length. Wire-feed speed is set at the control panel. Current and voltage adjust automatically.



Other features of the automatic Fillerarc equipment include all-position operation; a compact, combined operator station-control panel with two push buttons to control the entire welding operation; adaptability to light or heavy-gage materials; easy tack welding by opening and closing the starting circuit; and a crater-filling circuit which is available to taper wire speeds at the end of the weld.

Descriptive bulletin GEC 1334 gives complete specification on this G-E development. Write directly to the company for your copy.

ACID BRUSHES, all sizes Numbers 1, 2, 3 & 4. Exceptional quality, prompt service, production 500 gross daily.

STAINLESS STEEL WIRE SCRATCH BRUSHES, all types. For welding and all industrial use.

AUTO RADIATOR CORE BRUSHES, accepted standard and quality.

All our brushes have exceptional market values, service remains good as it has for past two decades.

Wm. D. MacGuffin Company
4262 Clybourn Avenue
Burbank, Calif.

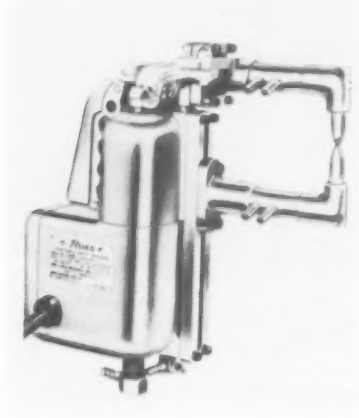
Soldering

To take care of the demand for a small can of regular soldering flux for those who have only occasional use for such a product, the Lake Chemical Co., Chicago, Ill., has just placed on the market a 2-oz can known as LA-CO Flux. This self-cleaning, nonacid flux can be used with 40–60, 50–50, 60–40, 95–5 solders for a wide variety of work.

Sample and further information may be obtained by writing the Lake Chemical Co., 3052 W. Carroll Ave., Chicago 12, Ill.

Portable Spot Welder

Ross Machine Tool Co. of Chicago Ridge, Ill., announce a new portable spot welder, now in full production, which features a built-in electronic timing control, thyrotron type, operating a solenoid contactor. This self-contained unit, completely water cooled, is encased in an aluminum housing. Some of the other features include: high amperage (over 17,000 at point of weld); throat depth of 6 in. with variable opening from 3 to 11 in.



Free illustrated folder containing complete data and prices is available on request from manufacturer, Ross Machine Tool Co., PO Box 122, Chicago Ridge, Ill.

Engine-driven Welder

A new 200-amp engine-driven welder, for pipe-line welding and all types of construction and maintenance work, has been announced by the General Electric Co. Welding Department. Designated Type WD20AG, the new welder is NEMA-rated for a current range of 40–250 amp. and will handle all d-c or a-c/d-c electrodes from $^1/_{16}$ to $^1/_4$ in. with excellent welding characteristics according to company engineers.

Welding performance is featured by: (1) minimum load drop-off as the welder heats up, (2) "peppy" arc and fast response, (3) ease in arc starting and (4) a high instantaneous recovery voltage that prevents popouts, the engineers say.

The liquid-cooled Hercules engine operates at 1750 rpm and has a 17-gal fuel tank which will keep the generator running over 13 hours at full-load rating, 60% duty cycle, on a tank full of gasoline, according to G-E engineers.

Descriptive Bulletin GEC-1333 gives complete operating data and specifications. Write directly to the company at York, Pa.

Kits for Welding Thermoplastics

The need for tools, supplies or information regarding welding thermoplastics on a frequent or occasional basis, by many companies, is now met by complete kits available from the American Agile Corp., PO Box 168, Bedford, Ohio.

Each kit includes two books, *Welding of Plastics* and *Plastics Welding Manual;* a 110-v welding gun with nozzle; 15 ft of nitrogen hose; electrical connections; a nitrogen flowmeter with tubing; a contour marker; a porosity spark tester; marking crayons; and a cutting-trimming knife.

Further information may be obtained from American Agile Corp.

Welding Smoke Consumer

A new electronic device for the elimination of smoke and dust from welding operations has just been put on the market by Papec Machine Co., Shortsville, N. Y., after extensive use in its own plant and in convention demonstrations. No venting to outside air is needed. The electrostatic filter, fan and controls are housed in a sturdy, portable cabinet which also serves as a convenient welding bench.

In normal use filter is cleaned twice a month by compressed air in less than 20 min downtime. Filter may also be water cleaned. Dimensions of unit as shipped completely assembled: 47 x $42^1/_2$ x 36 in. high; weight: 460 lb.

Air flow carries smoke and fumes away from the operator and into the filter. Welding visibility is said to be much improved and operator fatigue is reduced. A grating in the cabinet top provides a 24- x 24-in. welding area. The bulk of the spatter drops through to a spatter trap below.

If it's a
"HI-AMP"
You KNOW

You've bought the BEST

Reports received from throughout the Country—wherever Welding is a factor—indicates that Welders, when asked about performance and durability of Electrode Holders and Ground Clamps, invariably reply in substance—"if it's a 'HI-AMP', you KNOW you've bought the BEST."

Claims of superiority, for *any* product, is the natural prerogative of *any* manufacturer—but the proof of performance must come from the user. Perhaps that's why "HI-AMP" sales are going up-up-up! Need we say more?

Sold only through Welding Supply Distributors throughout the U. S. and Canada.

WAGNER MFG. CO.
350 W. 1st SOUTH ST.
JACKSON, MISSOURI

Weld with Wagner

NEW LITERATURE

New Specification Covers Carbon and Low-Alloy Steel Electrodes

An improved and enlarged edition of the "Specifications for High Tensile and Low-Alloy Steel Covered Arc-Welding Electrodes" has just been issued jointly by the AMERICAN WELDING SOCIETY and the American Society for Testing Materials.

The new edition (AWS A5.5; ASTM A316) classifies the electrodes by chemical analysis in addition to the usual classification by mechanical properties. This new method of classification will permit the consumer to choose low-alloy steel electrodes that will not only provide weld metal of specific mechanical properties, but also give weld metal more closely matching the base metal in corrosion resistance and other properties.

The new revision provides details on test methods, test requirements, standard sizes and lengths, packaging and marking. Handy tables classifying the electrodes along with their properties, characteristics and composition are also included.

An appendix provides a useful guide to the understanding and best use of the specification.

Copies of this specification in pamphlet form are available from the AMERICAN WELDING SOCIETY, 33 W. 39th St., New York 18, N. Y., at 40 cents each.

Electrode Selector Guide

To help users select the proper Arcaloy stainless steel electrode to meet their particular requirements, Alloy Rods Co., York, Pa., has published a new Electrode Selector Guide.

The Selector Guide, a two-color, four-page bulletin, gives the Arcaloy designations, electrode data and application data for 22 of the most popular stainless steel electrodes in the Arcaloy line.

To receive your copy of the new *Arcaloy Stainless Steel Electrode Selector Guide* write: Department 61, Alloy Rods Co., Lincoln Highway West, York, Pa., and be sure to ask for Bulletin AR-10.

Resistance Welders

Sciaky Bros., Inc., 4915 W. 67th St., Chicago, Ill., introduces Bulletin 334-3, completely describing the Sciaky Type PMCO 2 ST air-operated, press type, patented three-phase Modu-Wave Spot Welder—the so-called "standard of the aircraft industry."

This brochure fully describes and is supplemented with illustrations on the Sciaky patented three-phase Modu-Wave principle of operation that readily satisfies military and aircraft specifications.

For more complete information write direct to the Chicago office, Department L-2, for your free copy of Bulletin 334-3.

Design Manual

A new publication by United States Steel, *Design Manual for High Strength Steels*, is now available as a working handbook for architects and engineers.

The booklet contains technical information needed by an engineer in applying the use of high-strength low-alloy steels. It contains numerous charts and formulas, not only for high-strength steels, but also for structural carbon steel, and can be used as a multipurpose design manual.

Copies may be obtained by writing to U. S. Steel Corp., 525 William Penn Place, Pittsburgh, Pa., referring to publication number ADVL-215-54.

WRC Bulletin No. 23

The Welding Research Council has just issued Bulletin No. 23, *Cracking of Simple Structural Geometries*, covering extensive investigations by the Ship Structure Committee on (1) The Effects of Edge Preparation; (2) Interrupted Longitudinal Members; (3) Effects of Fastenings on Cleavage Fracture; (4) Effect of Welded Pads on Tension Members.

This bulletin consists of 24 pages and is priced at $1.00 per copy. Limited edition. Copies may be ordered through the AMERICAN WELDING SOCIETY, 33 W. 39th St., New York 18, N. Y.

Arc Spot Welding

"Spot Welding from One Side—with a Portable Gun," a 12-page reprint of an article that appeared in the April 1955 issue of *Product Engineering* is now available from Air Reduction Sales Co.

Aircospot, Air Reduction's inert-gas-shielded tungsten-arc spot welding process, is completely described. Over 30 tables, weld cross section and application photographs, drawings and graphs are included in the article. Sections of the text are devoted to "when to consider spot welding from one side," "how the equipment operates," "standards and test procedures," "factors affecting weld quality" and "applications."

Request a copy by writing Air Reduction Sales Co., a division of Air Reduction Co., Inc., 60 E. 42nd St., New York 17, N. Y.

Positioners

A new bulletin on Positioners issued by Worthington Corp. outlines seven basic points for consideration in the selection of positioners for various operations such as welding, coating, surfacing, chipping and other industrial operations where handling and positioning of work are required.

Effective methods in selecting the right positioner are informatively explained along with photographs illustrating various component parts. Also included is information on table rotation and tilt range, maintenance and repair, range and selection of variable speed drives and safety features.

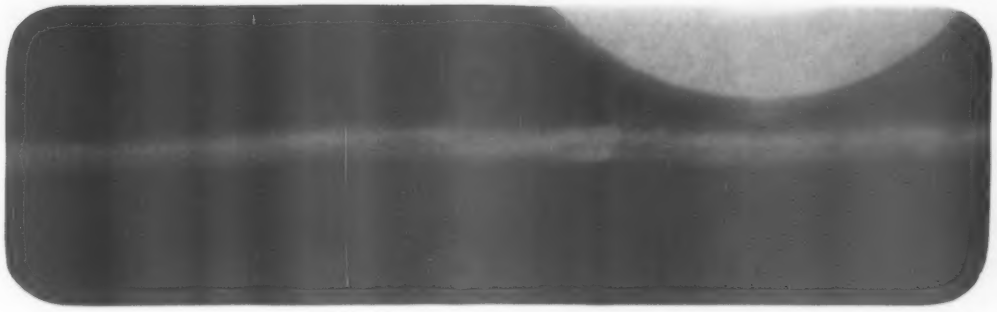
For further information or copies address requests to Advertising & Sales Promotion Department, Worthington Corp., Harrison, N. J., specifying Bulletin No. R-1700-B15.

Soldering Chart

Alpha Metals, Inc. of Jersey City, N. J., announces that new literature is now available, showing some of their "Special Soft Solder Alloys" in chart form. This bulletin also contains brief descriptions of the alloys and some of their suggested uses.

For your copy, write to Alpha Metals, Inc., 56 Water St., Jersey City 4, N. J.

Welding builds it faster, lighter and safer...



and RADIOGRAPHY checks each weld.

It swims. It climbs. It fights. It's tough and strong. For, from stem to stern, this L. V. T. is welded.

Welding saves precious weight and countless man-hours in construction. It avoids the rivets and bolts which become as lethal as shell fragments under shock.

With Radiography checking for soundness, welding continually finds new work to do—solves problems that would make jobs like this L. V. T. virtually impossible.

So weld shops, with small operations or large, are finding radiography valuable both for building reputations for good work and for expanding into new fields. If you would like to explore how Radiography can help you increase your business, get in touch with your x-ray dealer. He'll gladly talk it over.

RADIOGRAPHY

... another important example of photography at work

Kodak

EASTMAN KODAK COMPANY
X-ray Division, Rochester 4, N.Y.

Portable Remote Control

A new bulletin on *"Arctrol," Portable, Remote Control for Arc Welding Machines*, has been issued by the Worthington-Mullenbach Controls Division of Worthington Corp.

The new bulletin offers information on simplicity of operation, details of construction, installation and advantages of the "Arctrol"; a portable remote control for adjusting amperage on all makes of arc welders.

For further information or copies address requests to Advertising & Sales Promotion Department, Worthington Corp., Harrison, N. J., specifying Bulletin No. R-1700-B17.

D-C Welder

Complete information on the new Vickers Controlarc Magnetic Amplifier Rectifier D-C Welder is contained in a bulletin just published and available from the manufacturer, Vickers Electric Division, Vickers, Inc., St. Louis, Mo., a unit of the Sperry Corp.

In addition to photographs of the new welder and its components, the bulletin includes full details on the Controlarc's benefits, construction and operation and operation features, performance charts, electrical specifications and ratings, dimensions and weights and optional accessory equipment.

A copy of the bulletin may be obtained without charge from the manufacturer, Vickers Electric Division, 1815 Locust St., St. Louis 3, Mo.

•

Welding Applications

A new four-page two-color folder TIS 2496 showing profitable applications for "low heat input" metal joining on all base metals is available from Eutectic District Engineers and by writing Technical Information Service, Eutectic Welding Alloys Corp., 40-40 172nd St., Flushing 58, N. Y.

The folder is a guide to getting maximum savings through use of Eutectic "low temperature welding alloys." Procedures for many common metal joining jobs are discussed. Techniques and alloy recommendations are given for cast-iron repair without preheat and for joining steels easily with extremely high joint strengths.

•

RWMA Leaflet

The Resistance Welder Manufacturers' Association, composed of 15 of the leading manufacturers of resistance welding machines and equipment, has greatly facilitated the usage of the process in metal fabrication of all types and in the past decade has made great strides in informing manufacturing industries how to produce faster at lower cost and with improved design and durability.

Education, through the publication of the *Resistance Welding Manual*, the numerous technical bulletins and a complete course in Resistance Welding, has made it possible for metal fabricators to train their engineers and shop foremen in the latest resistance welding practices.

Mechanical and electrical standards for resistance welding machines have been developed by the Association's Technical Committee and are widely used by industry. These educational and technical aspects of RWMA's activities have been aided by their research program, which has been a continuing part of their endeavors for a number of years.

These contributions to the advancement of industrial usage of resistance welding, and other phases of the Association's work, are covered in a leaflet recently published by the Resistance Welder Manufacturers' Association, 1900 Arch St., Philadelphia 3, Pa. Copies of this are available upon request. The leaflet also lists the bulletins and literature available from the Association at cost.

BERNARD

PIONEER FOR MODERN WELDING

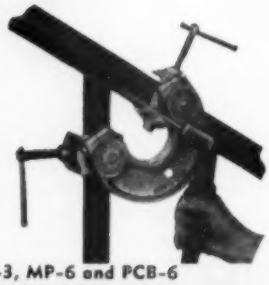
"Shortstub" ELECTRODE HOLDER

The jaws substitute for stub waste by splicing a 2 inch extension to the length of every electrode.

"Multi-Pic" CONTOUR CLEANER

Delivers FIVE surface cleaning blows with each swing and lasts FIVE times longer than single headed hammers.

"Pro-Clamp" MECHANICAL HANDS



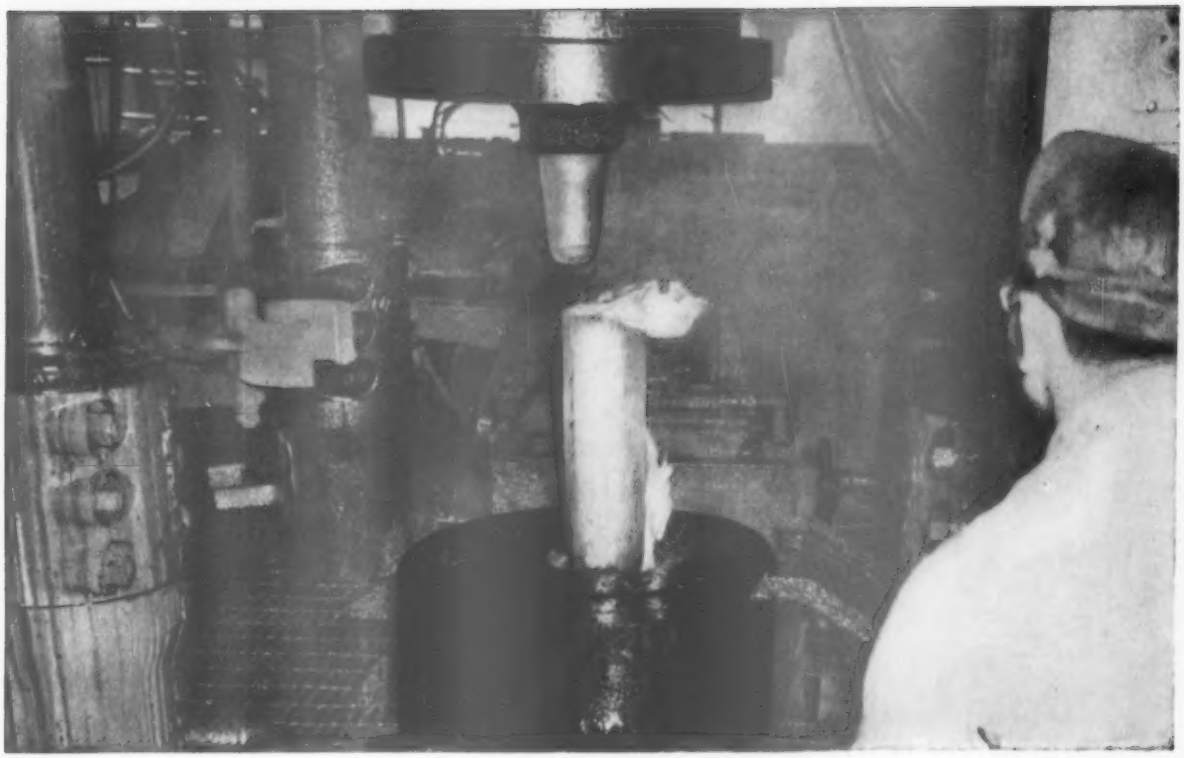
MODERNIZE the fabrication of plates, shapes, rods, bars, pipes, etc. MAKE fitting, positioning, holding, and welding a fast, accurate, inexpensive, one-man job.

See your Local Dealer, or, Write For Bulletins, SS-3, MP-6 and PCB-6

Mfg. by

BERNARD WELDING EQUIPMENT CO.

10230 SOUTH AVE. N • CHICAGO 17, ILLINOIS



Die Pot Life Increased 350 Per Cent

A deposit of HASTELLOY alloy C hard-facing rod has more than tripled the service life of the die pots used in this slugging and piercing operation. The hard-faced parts are exposed to severe impact and abrasion at high temperatures. Press tonnages required to perform the operation have been reduced from 30 to 50 per cent since the pots have been faced with HASTELLOY alloy C. This rather unusual plus value is due to the low friction characteristics of this nickel-base alloy.

Resists Chipping and Spalling

HASTELLOY alloy C is a tough, machinable, hard-facing alloy that can be applied to all common die steels. It has high tensile strength, good ductility and excellent resistance to chipping and spalling. It can be applied by the metallic-arc process, flows smoothly, and produces sound deposits. No special heat-treating or cooling procedures are needed.

No Grinding or Peening

When deposited, HASTELLOY alloy C has a hardness of 210 Brinell, and can be machined easily by ordinary die-sinking tools. Then the deposit work hardens, in service, to about 375 Brinell without deformation. Its work-hardening characteristics eliminate the necessity for peening the deposit to obtain maximum wear-resistance.

For information on procedures for applying and for available sizes and prices, write for the booklet "HASTELLOY Alloy C—A Machinable Hard-Facing Alloy."

"Haynes" and "Hastelloy" are registered trade-marks of Union Carbide and Carbon Corporation.

HAYNES TRADE-MARK ALLOYS

HAYNES STELLITE COMPANY

A Division of Union Carbide and Carbon Corporation

UCC

General Offices and Works, Kokomo, Indiana

Sales Offices

Chicago · Cleveland · Detroit · Houston · Los Angeles · New York · San Francisco · Tulsa

How miller welders helped seal the arteries of America's largest single purpose power plant...

Substantial monument to Free Enterprise is OVEC and IKEC, suppliers of electric power to the Atomic Energy Commission's new uranium diffusion center in Pike County, Ohio.

Ohio Valley Electric Corporation and its subsidiary, Indiana-Kentucky Electric Corporation, agreed to supply electric power to this great new atomic production center . . . *15 billion kilowatt-hours annually.*

Two huge generating stations are being built: The Kyger Creek Plant at Cheshire, Ohio will have five generating units of 200,000 KW each; Madison, Indiana's Clifty Creek plant will produce 1,200,000 KW with its six big generators. Each of the eleven turbo-generating units will operate off a single boiler, with super-heated steam reaching 1,050 degrees Fahrenheit under 2,000 lbs. pressure per square inch! The high temperatures and reheat, which the sponsor companies have pioneered in their own right, will make these two plants among the most economical, most efficient generating stations in the country.

Miller Selenium Rectifier d-c Arc Welder, in four wide-range models. For complete, concise, worthwhile information on these and other Miller Arc and Spot Welders, contact us today . . . at no obligation, of course.

These same elements, however, make the fabrication of faultless high-pressure steam lines vital . . . and extremely difficult. To accomplish this extremely important task, pipe welding specialists equipped with the maximum of engineering skill utilized the Miller Selenium Rectifier d-c Arc Welder.

". . . . if it's Miller, you know it's the *finest!*"

miller

ELECTRIC MANUFACTURING COMPANY, INC.
APPLETON, WISCONSIN

INDEX TO ADVERTISERS

Air Reduction ..... Outside back cover
All-State Welding Alloys Co., Inc. 799
The American Brass Company ..... Inside back cover
American Chain & Cable 796, 797
Anti-Borax Compound Co. 819
Arcos Corporation 800, 801
Aronson Machine Company 812

Bernard Welding Equipment Co. 828

Champion Rivet Co. 810
Columbia Electric Mfg. Co. 819
Crucible Steel Co. 807

Dockson Corporation 811

Eastman Kodak Company 827

Fibre-Metal Products Co. ..... Inside front cover
Fulton Auto Exchange 818

General Electric 792, 793

Haynes Stellite Company, A Division of Union Carbide and Carbon Corp. 829
Hobart Brothers Co. 723

International Nickel Co. 728, 787

Linde Air Products Company, a Division of Union Carbide and Carbon Corp. 726
Liquid Carbonic Corporation 806

William D. MacGuffin Company 824
P. R. Mallory & Co., Inc. 725
Metal & Thermit Corporation 724
Miller Electric Manufacturing Co., Inc. 830

National Carbide Company 815

Page Steel & Wire Division 796, 797

Square D Company 809
Stulz-Sickles Co. 814

Tempil® Corporation 730
Tube Turns 803, 804

Union Carbide and Carbon Corporation
Haynes Stellite Company 829
Linde Air Products Company 726

Vickers Electric Div., Vickers, Inc. 813
Victor Equipment Company 821

Wagner Mfg. Co. 825
Westinghouse Electric Corp. 819

W. SPRARAGEN, DIRECTOR

WELDING RESEARCH COUNCIL
OF THE ENGINEERING FOUNDATION

SUPPLEMENT TO THE WELDING JOURNAL, AUGUST, 1955

TENSION-IMPACT PROPERTIES OF AUSTENITIC STAINLESS STEELS AT AMBIENT AND LOW TEMPERATURES

Static and dynamic properties of several stainless steels determined for base metal and for butt-welded assemblies

BY A. CHOQUET, V. N. KRIVOBOK AND G. WELTER

FOREWORD. The utilization of austenitic stainless steels as a material of construction has been, mostly, in the transportation industry, such as railway, trucks and aircraft. In fact, a book dealing with various design criteria, mostly calculated from known properties of stainless steels, was compiled for the use of engineers engaged in transportation design and its problems.[1]

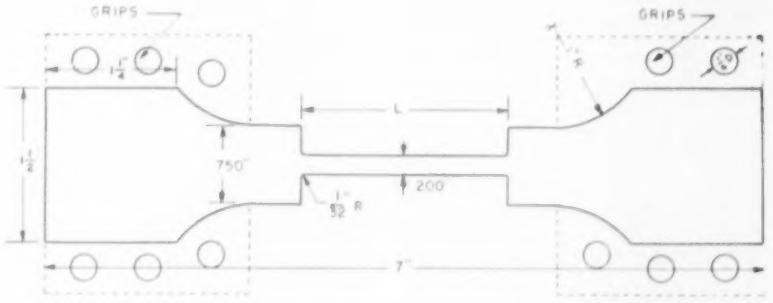
Except for general information on impact properties of stainless steels, secured, as is well known, on the basis of a rather arbitrary method, the behavior of stainless steels under dynamic stresses has not received much attention. Yet, such behavior is of much technical interest. It is fully recognized, of course, that examination of laboratory-scale specimens, as has been done in the present case, yields information of relative rather than precise nature. Yet, even "relative" data supply *basic* information related to the specific properties and characteristics of austenitic stainless steels. It is on the basis of this belief that this paper was written.

Scope of Investigation

This investigation was conducted on stainless steels of commercial designation such as 1/4 and 1/2 hard, since it is at these levels of strength that stainless steels are employed in stressed parts. A steel of another composition was added, namely, 16% chromium, 16% manganese and 1% nickel. At the time this investigation was conceived and begun, the unavoidable shortage of nickel brought on a government regulation under which the transportation industry was restricted in the use of stainless steels containing no more than 1% of nickel. The last-mentioned steel was offered and, for a period of time, was used as a substitute for the regular grades of austenitic stainless steels. Later on in the investigation, a few tests were made on low-alloy steels to provide initial data on behavior of these materials of construction under conditions of testing as described elsewhere in this paper.

The common method of assembly of such steels is by welding. Thus, it seemed most desirable to ascertain, at least in general terms, not only of their relative dynamic strength, but also ascertain the effect of the heat of welding, if any, on the properties of the base metal. For the above reasons welded samples were included in the program.

Static tension and compression properties of austenitic stainless steels are



"L" Gage Length: 4", 2", 1", .250", .040".

Welded Specimens: Similar to above with a .20" wide weld at the middle of gage length "L"

Fig. 1 Specimen design for materials tested

A. Choquet and G. Welter are Members of the Staff and Professor of Applied Mechanics, respectively, École Polytechnique, Montreal. V. N. Krivobok is Head, Stainless Steel & Heat Resistant Alloys Section, International Nickel Co., Inc., New York, N. Y.

Presented at 1955 AWS National Spring Meeting held in Kansas City, Mo., June 7-10, 1955.

Table 1—Chemical and Mechanical Properties of the Four Stainless Steels Tested

Chemical*

Steel	Source	Heat No.	% C	Cr	Ni	Mn	P	S	Si	Other
17-7 120,000 T. S.	U. S. Steel	26225	0.08	17.04	7.82	1.15	0.031	0.030	0.40	....
17-7 127,000 T. S.	Wash. Steel	7X9206	0.09	17.02	7.47	1.32	0.03	0.02	0.32	....
17-7 167,000 T. S.	Wash. Steel	20352	0.097	17.12	7.13	1.20	0.029	0.020	0.44	....
16-16-1 111,000 T. S.	U. S. Steel	8X7969	0.08	15.64	0.93	17.17	0.025	0.006	0.50	N = 0.16

Mechanical*

Steel	Source	Heat No.	Temper	Tensile strength, psi	Elongation in 2 in., %
17-7 120,000 T. S.	U. S. Steel	26225	Annealed	120,000	43.0
17-7 127,000 T. S.	Wash. Steel	7X9206	1/4 hard	127,000	45.0
17-7 167,000 T. S.	Wash. Steel	20352	1/2 hard	167,000	25.0
16-16-1 111,000	U. S. Steel	8X7969	Annealed	112,700 long. 110,900 trans.	47.0 long. 46.0 trans.

* Provided by the mill.

so affected by variations in composition, as well as processing, such as cold rolling, for example, that it is customary to stipulate the above properties to be within certain limits adopted in general in strength specifications for cold-rolled steels. If true comparisons are to be made between static and dynamic properties, it is imperative to know, with certainty, the static tension properties of the given steels. For this reason, static tests essential for the purposes of this investigation were incorporated in the test program.

The suspected dependence of the steels' ability to withstand dynamic forces on *metal volume* were studied by incorporating five different gage lengths. This study was accomplished by means presently described of evaluating the volume of metal absorbing the force (stress) under impact testing thereby determining the amount of impact energy absorbed per unit volume of metal under test. The principle was that of measuring that volume of the test piece which was *plastically* deformed during testing and using this volume by subsequent calculations. No attempt was made to measure elastic energy. Thus, the values recorded elsewhere in this paper are only of relative significance, illustrating the characteristics of the steels rather than furnishing numerical data on dynamic strength.

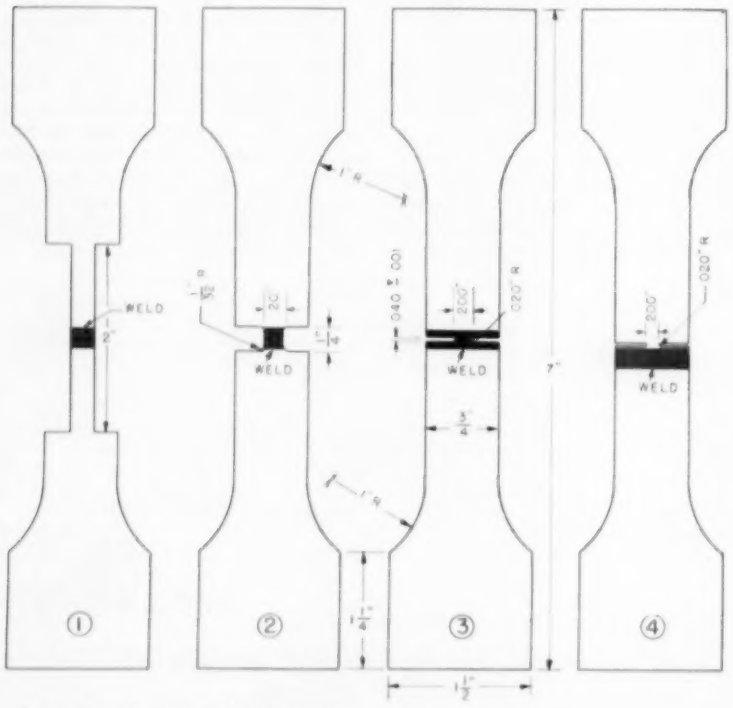


Fig. 2 Design for butt-welded specimens

Description of Test Equipment

Stainless steel sheets of between 0.082 and 0.070 in. thick were used for the tests. The chemical and mechanical properties of the steels are given in Table 1.

The test specimens from this steel were in two forms: base metal and butt welded. Base metal sheet specimens were sheared in 10- x 1 5/8-in. strips and prepared for test by machining as shown in Fig. 1. Butt-welded specimens were provided in the as-welded condition by Pullman Standard Car Mfg. Co. Hand welding was done using 29-9 welding rod for welding long strips, later sheared as stated above, the end strips being discarded. The specimens were then machined to various configurations as shown in Figs. 1 and 2. On the butt-welded samples, in addition to the 4-, 2-, 1-, 1/4-and 0.040-in. gage lengths used with the base metal tests, another test piece was tested in which the 0.040-in. slit was made at 1/16 in. away from the weld proper, presumably in the heat-affected zone (see Specimen 4 in Fig. 2). All test specimens were first squared off in the milling machine, had their shoulders milled and their gage length

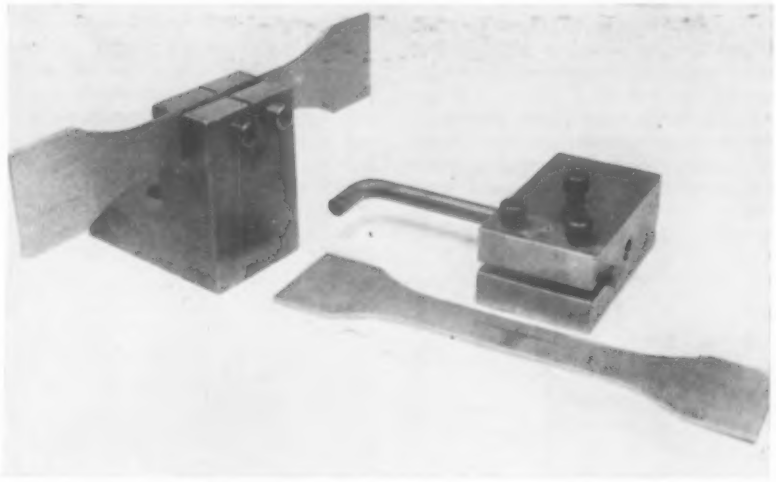


Fig. 3 Jigs for machining 0.040-in. gage specimens

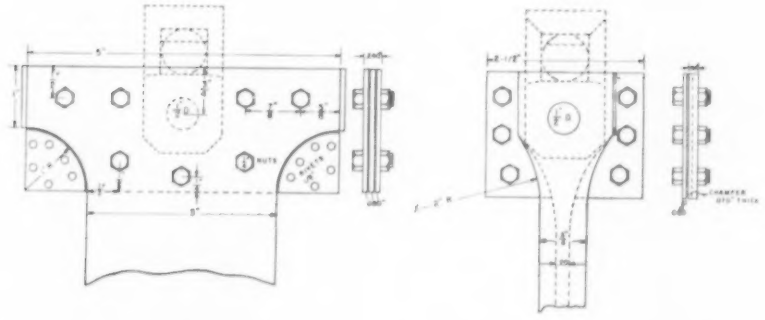


Fig. 4 Specimen grips

machined on one side. They were then turned over and machined similarly on the other side.

Figure 3 shows two jigs that were made to assist in the machining of the 0.040-in. gage specimens. One was designed* for drilling two 0.040-in. radius holes at a 0.240 in. distance, center to center. The other jig was designed* to open up the slit to reach the drilled hole with a 0.040-in. metal slitting saw. Each specimen was examined under a × 10 magnification, and if the joining of the half circumference and the slit proved defective, it was rejected.

To insure that the full impact is transmitted to the gage length of the specimen and that no slippage of deformation occurs to the specimen ends, the grips were so constructed that a snug fit was obtained. The heads of the specimen are fitted (oftentimes by hand filling) into a recess in one pair of the grips. The grips and specimen are then mated with a cover plate and clamped with six screws as shown in Fig. 4. Figure 5 illustrates these partially assembled special gripping devices with test specimens.

"Mechanics Lay-Out Marking Blue" was used to cover the whole gage length and the immediate vicinity of the shoulder to detect the extent of plastic deformation and to assist in evaluating the deformation in each specimen tested. A grid of 0.05 in. wide squares was precision-scribed with sharp pointed needles. To insure proper distance, a two-directional, graduated Vickers Hardness Machine block or spacer, shown in Fig. 6, was used to scribe the specimens. Specimens to be tested at −40° F and lower temperatures were scribed with a slightly heavier pressure, producing by these means a lightly scratched metal surface. The grid so inscribed was then photographed before test and subsequently enlarged for precision measurements. Following either static or dynamic testing of the specimens, the grid was again photographed so that it could be compared with the "before test" photograph. Comparison of these photographs permitted measurements and calculations of the "local," i.e., in each grid unit, percentage elongation. In a few cases, when desirable, similar measurements were made of reduction in width and thickness.

The use of grids permitted the evaluation of the impact testing not on the basis of *total energy absorbed in testing*, but on the much more realistic basis of energy (in proper units) *per unit of volume of the material under test*.

It should be agreed that the energy absorption under impact testing is proportional to the quantity of metal concerned in the plastic deformation, plus, of course, the energy of elastic behavior. If a record of plastic deformation is available, it is then possible, with the aid of certain assumptions, to measure the volume absorbing energy and thus calculate energy absorption per unit volume.

The above record was obtained by means of the above-mentioned gridding of the samples and photographing the grids before and after the test. With appropriate measurements of the length, width and thickness of individual grids, one can actually calculate the volume of material that has been instrumental in absorbing energy. The calculations assumed a minimum of 10%* increase in either length or width of the individual grid, if that grid was to be counted into energy absorbing volume. Figures 7 and 8 illustrate the method well. The data then can be presented in units of energy per unit volume. In our case,

* Such small increments of gage length were measured (0.05 in.), that accuracy greater than 10% was not possible due to the distortion of lines during tests.

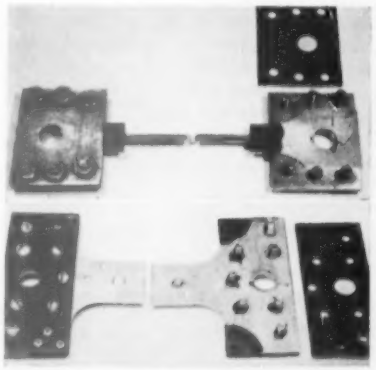


Fig. 5 Partly assembled gripping devices with broken specimens

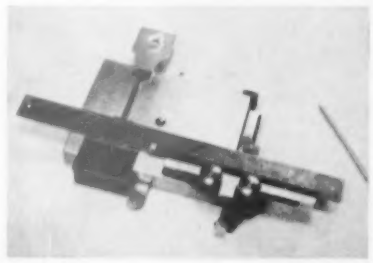


Fig. 6 Arrangement for grid tracing of specimens

* Designed by United Shoe Machinery Co., Montreal, Canada.

we selected ft-lb per cu in.

The static tension tests were performed on a Universal Baldwin Testing Machine with a 60,000 lb capacity, with the standard loading rate of about 0.05 in. per in. per min. The stress-strain curve for each sample was automatically recorded. Using this machine, the specimens and grips are joined by standard adaptations to the two cross bars of the machine as shown in Fig. 9.

The dynamic impact tests were performed on a standard (either 220 or 110 ft-lb) Riehle free-swinging pendulum machine. Impact speed was measured to be 18 fps when the pendulum falls from its higher station (220 ft-lb resultant) and 12.5 fps for its lower station (110 ft-lb resultant).

Energy absorption to cause rupture can be read directly from a graduated scale on the machine or calculated from the pendulum weight, angle of free

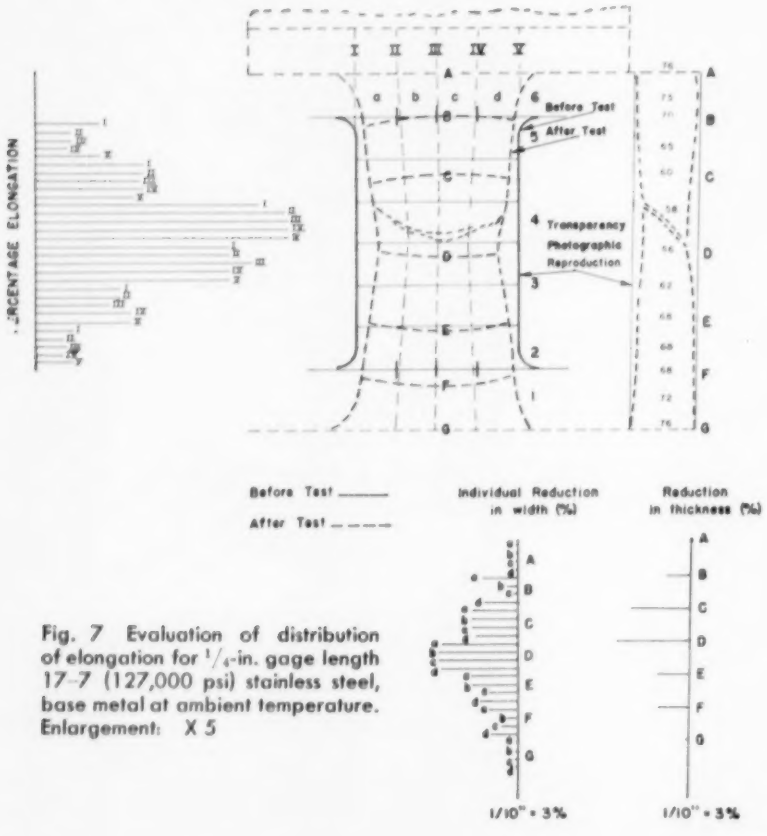


Fig. 7 Evaluation of distribution of elongation for 1/4-in. gage length 17-7 (127,000 psi) stainless steel, base metal at ambient temperature. Enlargement: X 5

Fig. 9 Specimen set for static tension test between the cross bars of the Baldwin machine

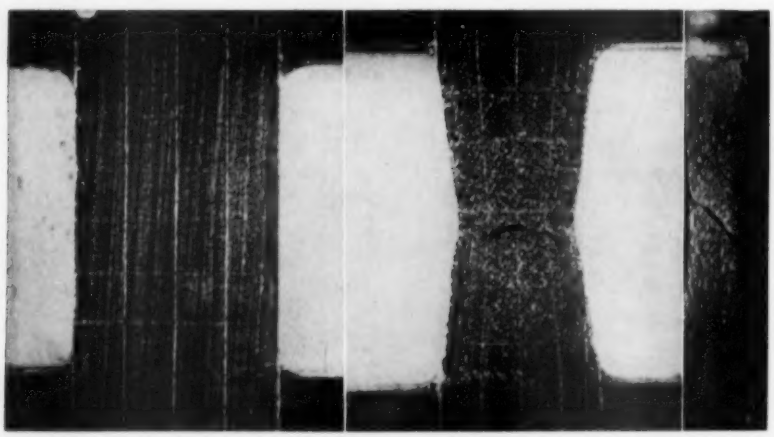


Fig. 8 Enlargement of 1/4-in. gage length base metal specimen before and after impact rupture at ambient temperature. X 6

Fig. 10 Riehle impact machine and close-up of pendulum disk with specimens, grips, tup and horns

falling and angle of rise after impact. Because of the added weight of the specimen, grips and attachments to the back of the free falling pendulum, the calculation method for energy absorption was judged to be more accurate and was used throughout this investigation.

The cycle of operation is as follows: the specimen is securely fitted into the grips. One end of the grip assembly is screwed into the back of the falling disk while the other is joined by a removable pin to a transversal "stop." At the instant of impact or when the pendulum has reached maximum velocity in its downward movement, the "stop" hits on the two horns extending on each side of the pendulum frame (see Fig. 10). The length of the horns has been made adjustable in order that samples of different gage lengths would have available a full amount of potential energy of the falling pendulum.

For testing at temperatures below normal, both grips and specimens were cooled for 10 min in methyl hydrate and carbon dioxide (dry ice) to −42° F. The specimen could be removed from the coolant and fixed by means of a pin to the back of the pendulum already set to its high or low station in only a few seconds. Then the arm release was pulled. Earlier experiments have shown the specimen to be at −40° F when actual impact occurred. Chloroform and carbon tetrachloride, respectively, were also used instead of methyl hydrate with the dry ice to obtain the −42° F test temperature. With these latter mixtures, the mechanic's "lay-out blue" used for the gridding of the specimens was not dissolved.

For low-temperature static tension tests, the specimen was placed in a 15-in. long, 8-in. diam jacket containing the cooling liquid while being held in testing position between the cross bars of the Baldwin machine. Thus, the specimen was immersed in the liquid at −40° F during the test. Constant temperature control could be maintained by the addition of small lumps of dry ice.

Table 2—Static Test Results of Base Metal

Steel	Gage length, in.	Tensile strength, psi (avg*) Ambient temp	Tensile strength, psi (avg*) −40° F temp	Elongation, % Ambient temp	Elongation, % −40° F temp	Energy absorbed, ft-lb (avg*) Ambient temp	Energy absorbed, ft-lb (avg*) −40° F temp
17-7	0.04	141,200	185,000	..	..	10.2	11.1
120,000 psi	1/4	131,900	...	60.0	..	27.0	...
(Heat 26225)	1	123,400	...	41.0	..	54.0	...
	2	119,000	169,250	33.0	31.0	82.0	94.0
	4	122,900	...	37.0	..	192.0	...
17-7	0.04	146,600	191,400	..	..	15.0	19.5
127,000 psi	1/4	133,000	178,700	63.0	56.0	34.5	36.7
(Heat	1	129,000	178,800	48.0	38.0	85.5	82.0
7X9206)	2	121,700	177,800	40.0	32.0	129.5	125.0
	4	128,300	...	37.0	..	233.2	...
17-7	0.04	180,100	211,500	..	..	10.6	22.5
167,000 psi	1/4	166,100	...	34.0	..	24.5	...
(Heat 20352)	1	166,500	...	27.0	..	59.5	...
	2	161,200	195,700	21.0	26.0	110.0	125.1
	4	159,300	...	19.0	..	158.0	...
16-16-1	0.04	135,000	166,000	..	..	12.6	12.0
11,000 psi	1/4	119,500	151,000	68.0	72.0	31.0	42.0
(Heat	1	114,500	153,800	48.0	62.0	71.0	122.0
8X7969)	2	113,500	149,100	40.0	56.0	113.0	209.0
	4	108,700	...	35.0	..	179.5	...

* Results of two, three or four tests.

Table 3—Static Test Results of Butt-Welded Metal

Steel	Gage length, in.	Tensile strength, psi (avg*) Ambient temp	Tensile strength, psi (avg*) −40° F. temp	Elongation, % Ambient temp	Elongation, % −40° F. temp	Energy Absorbed, ft/lb (avg*) Ambient temp	Energy Absorbed, ft/lb (avg*) −40° F. temp
17-7	0.04	111,000	132,500	..	..	7	10.1
120,000 psi	0.04	141,200	168,500	..	..	6	11.2
(Heat 26225)	(Outside)						
	1/4	104,500	...	39	..	17	...
	1	103,300	...	16	..	22	...
	2	104,900	122,700	8	21	21.5	47.5
17-7	0.04	128,200	143,300	..	..	10	11
127,000 psi	0.04	139,700	182,700	..	..	14.5	19.5
(Heat	(Outside)						
7X9206)	1/4	119,000	136,800	48	29	19.5	20
	1	115,500	135,100	27	22	42	39.5
	2	119,700	140,700	29	20	94	70
17-7	0.04	111,600	132,000	..	..	7.2	8.5
167,000 psi	0.04	124,300	187,500	..	..	11.5	16
(Heat 20352)	(Outside)						
	1/4	104,500	...	53	..	18.5	...
	1	101,500	...	32	..	38.5	...
	2	99,300	122,000	23	7	49	22
16-16-1	0.04	112,500	136,000	..	..	5.5	7
111,000 psi	0.04	134,000	164,000	..	..	11	14
(Heat	(Outside)						
8X7969)	1/4	110,900	133,800	39	35	18	21
	1	109,500	132,000	29	25	40.5	48
	2	106,300	133,000	27	26	72	91

* Average of two, three or four tests.

Materials Tested

Four heats of commercially manufactured stainless steels of different strengths, a heat of so-called chromium-manganese stainless steel, two low-alloy steels and one plain carbon steel were used in this investigation.

The compositions of the steels and their mechanical properties as supplied by the processing mills are recorded in Table 1.

Test Results

I. Static Tension Tests

The results of static tension tests of the base metal and weldments of the same material at ambient and −40° F temperatures for gage lengths of 0.040, 1/4, 1, 2 and 4 in. are given in Tables 2 and 3.

(a) Results at Ambient and −40° F on Base Metal and Welded Samples. There was this reason for testing selected steels in tension: Basis has to be established for comparing the static strength of welded steels (location of failure) and the impact strength of both base and welded samples.

At first, it should be mentioned that a somewhat intriguing observation on base metal testing was made: samples (test pieces) of a short gage length, i.e., 0.04 and 1/4 in., showed a consistently higher tensile strength. As the gage length increased, the general tendency,

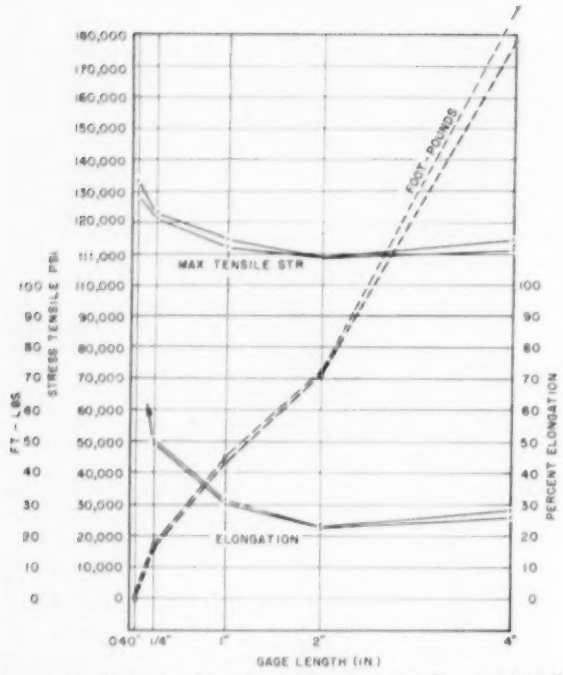


Fig. 11 Static tension test of base metal (heat 26225) at ambient temperature

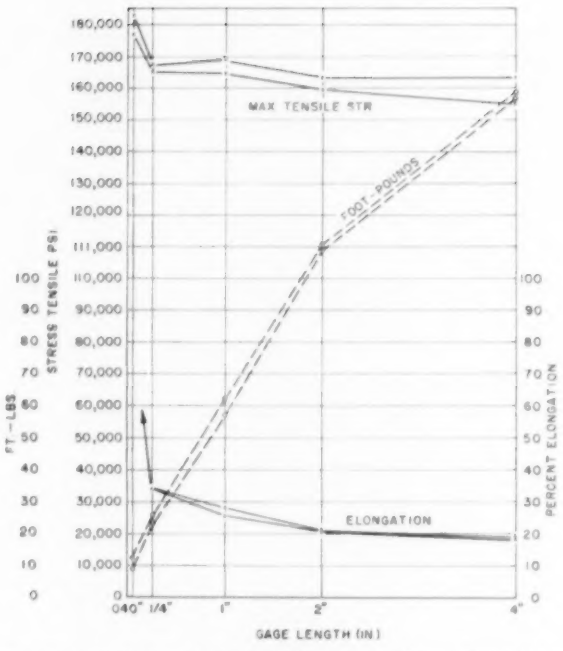


Fig. 12 Static tension tests of base metal (heat 20352) at ambient temperature

with a few exceptions, was for the tensile strength to decrease. The well-known method[3] for evaluating energy in static tension tests absorbed in fracturing metallic materials showed that a certain limited proportionality exists between the gage length (i.e., volume of the metal) and the energy, in ft-lb absorbed by the test sample. This is shown in Figs. 11, 12 and 13. The latter figure shows that the same relationship exists at low temperatures.

This observation is of interest since it reflects the ability of the investigated steels to strengthen through strain hardening. This will be obvious again later in the discussion of distribution of ductility.

It is regrettable that accurate testing of samples longer in gage length than 4 in. was not practical. As will be described later, the concept, so little used, of energy consumed in either static or dynamic testing yields interesting data.

The butt-welded samples required about $^1/_2$ to $^2/_3$ less energy, by comparison with the parent metal, to be ruptured.

In all cases, i.e. in all steels tested in the above described gage length, the tensile strength of the base metal at −40° F is considerably higher than it is at room temperature. As was just mentioned, the welded samples, always

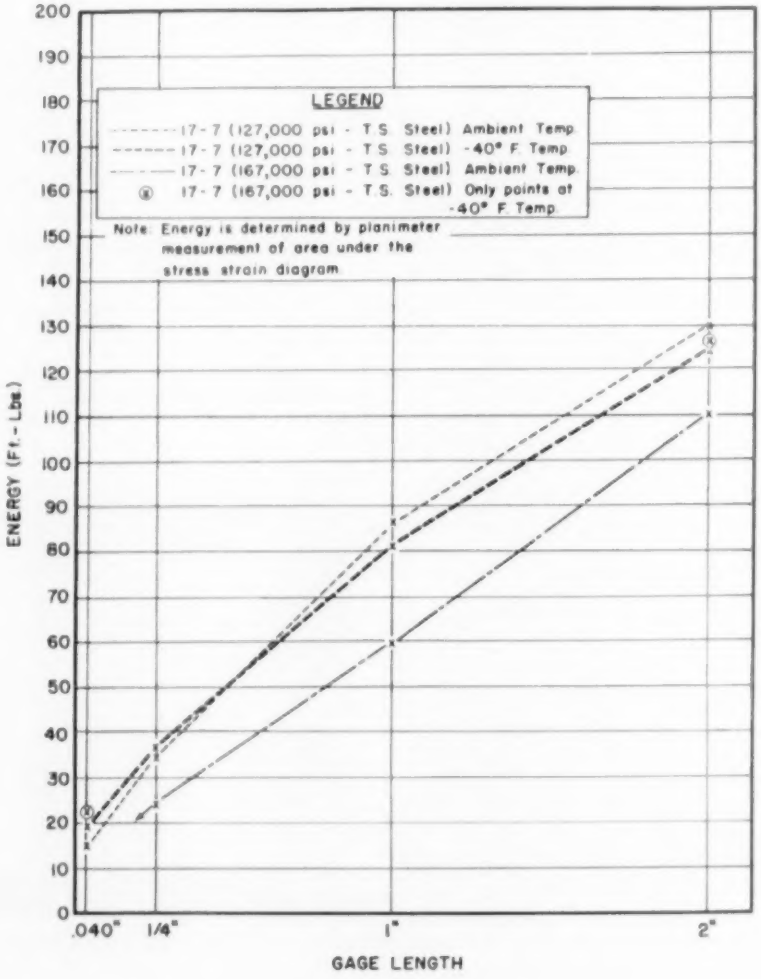

LEGEND
17-7 (127,000 psi - T.S. Steel) Ambient Temp.
17-7 (127,000 psi - T.S. Steel) -40° F. Temp.
17-7 (167,000 psi - T.S. Steel) Ambient Temp.
17-7 (167,000 psi - T.S. Steel) Only points at -40° F. Temp.
Note: Energy is determined by planimeter measurement of area under the stress strain diagram
ENERGY (Ft.-Lbs.)
GAGE LENGTH

Fig. 13 Static energy of the base metal of the two steels tested at ambient and −40° F temperatures for the various gage lengths used

Table 4—Impact Results at Ambient and —40° F Temperatures of Base and Butt-Welded Material

Note: Energy expressed in ft-lb/cu in. Elongation measured on gage length as indicated below

Gage lengths, in.	Base Metal — Ambient Energy	Base Metal — Ambient Elong, %	Base Metal — −40° F Energy	Base Metal — −40° F Elong, %	Welded Samples — Ambient Energy	Welded Samples — Ambient Elong, %	Welded Samples — Ambient Location*	Welded Samples — −40° F Energy	Welded Samples — −40° F Elong, %	Welded Samples — −40° F Location*
				(*a*) Heat 26225—T. S. is 120,000 psi						
0.040	12,400	..	..	..	15,675	..	W	12,930	..	W
0.040 (outside)	..	..	..	..	13,100	..	W	23,700	..	W
1/4	5,680	48	5,820	47	3,750	40	W	5,200	41.5	W
1	4,265	42	4,330	37	2,050	22	W	3,760	34	W
2	4,930	38.5	5,650	35	1,835	20.5	W	2,960	28	W
				(*b*) Heat 7X9206—T. S. is 127,000 psi†						
0.040	14,700	..	19,550	..	16,850	..	HA	18,300	..	HA
0.040 (outside)	..	..	..	..	12,630	..	W	23,000	..	W
1/4	4,495	39	6,125	49	3,265	32	2HA, 1W	5,166	38	W
1	4,565	42	5,280	41	2,049	20	HA	3,483	30	W
2	3,930	34	4,570	37	2,056	18	HA	3,476	29	2W, 1HA
				(*c*) Heat 20352—T. S. is 167,000 psi						
0.040	16,225	..	20,650	..	17,000	..	W	16,700	..	W
0.040 (outside)	..	..	..	..	15,175	..	W	19,300	..	W
1/4	4,725	24.5	5,360	33	4,133	42	W	4,650	39	W
1	4,035	26	4,820	30	1,460	14.5	W	1,915	16	W
2	3,350	22.5	4,500	27	790	7.5	W	986	16	W
				(*d*) Heat 8X7969—T. S. is 111,000 psi						
0.040	15,725	..	18,320	..	..	..	..	..	..	..
0.040 (outside)	..	..	..	..	..	..	..	..	..	..
1/4	4,980	46	..	..	4,215	31	W	3,600	28	W
1	4,975	45	4,530	35	2,970	27	W	3,020	24	W
2	4,480	39	4,970	37	3,410	32	W	1,900	15	W

* Location of fracture—*W* = in the weld; *HA* = in the heat-affected zone.

† The results from the testing of this steel were unusual in that at gage lengths of 1/4, 1 and 2 in. of nine tests conducted at room temperature, only one failed in the weld, whereas, when tested at −40° F, only one sample failed in the heat-affected zone.

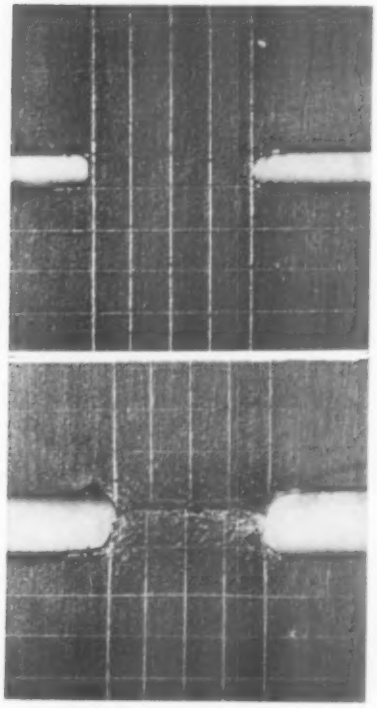


Fig. 14 Enlargement of 0.040-in. gage length specimen before and after impact rupture at ambient temperature. X 5

breaking in the weld, showed the tensile strength to be about of the same order, except again in the case of 0.04-in. gage length. This reproducibility of results shows the validity of our assumption that welding has been done with enviable care.

As in the case of the base metal, the tensile strength of the welds is considerably higher at −40° F than it is at ambient temperatures.

The ductility of either the base or weld metal has not been drastically reduced by testing at low temperatures. In fact, it can be considerably increased as was found out before and pointed out in the previous publication.[3]

II. Tension Impact Tests

(*a*) *Results at Ambient and −40° F Temperatures on Parent Metal.* The results of tension impact tests given in customary units of ft-lb read directly from the testing machine are recorded in Table 5. Three tests for each steel each gage length of the sample and each temperature where made and the results were sufficiently close to justify averaging the results. It would be noted at once that the experimental values, taken as a measure of the steel's tough-

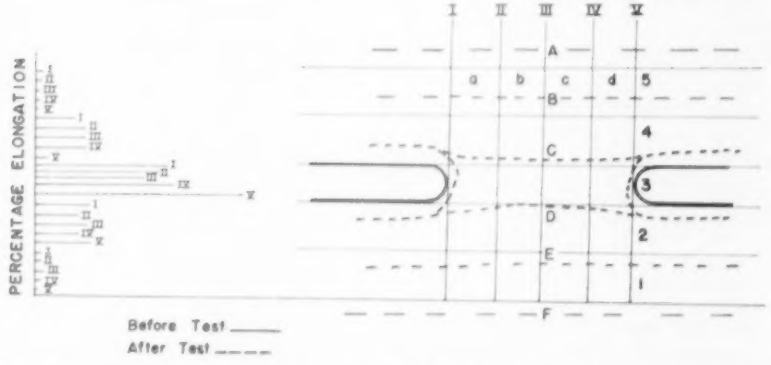


Fig. 15 Elongation and distortion in 0.040-in. gage length base metal (17–7) after impact at ambient temperature. Enlargement: X 6

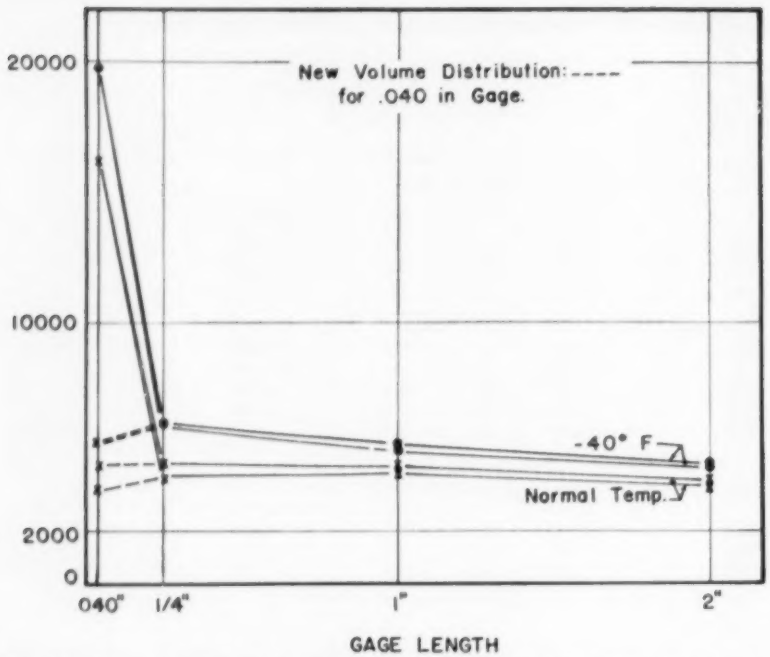


Fig. 16 Impact testing of base metal 16-16-1 (111,000 psi) stainless steel showing unit volume energy vs. gage length at both testing temperatures

ness, show great dependence upon the gage length of the test sample, as should be expected. Unless one is advised of the experimental conditions under which the above test records were secured, one is likely to conclude that the steels, represented by samples of short gage length, come perilously close to being brittle material: at least it may be added under conditions that might be assumed to be approaching notch or stress concentration, namely, at gage length of only 0.04 in.

Another observation is that energy required in tension impact is inversely proportional (or rather affected) by the tensile strength of the steel, contrary to the case of energy required in static tension. In the latter case, the absorbed energy, measured as an area under the stress-strain diagram,[2] is, obviously, governed by the tensile strength as well as the ductility of the given steel.

It has been noted before that energy values per unit volume for 0.040-in. gage length falls out of line with 16,000 to 20,000 ft-lb per cu in. value compared to approximately 5000 for the other three gages. Figures 14 and 15 show by the distorted lines that a quantity of metal within the shoulders of the 0.040-in. specimen are definitely concerned in the rupture: thereby explaining the high values obtained with this gage-length specimen. Calculations based on all regions, showing over 10% elongations when added to the material which forms the gage length, brings the value of 20,000 ft-lb per cu in. down to about 5000.

These "corrected" values, as we would like to term them, are shown by dotted lines as Fig. 16; except for inevitable experimental errors the energy required in rupturing all gage lengths under investigation are practically identical.

In Table 8 will be found interesting data: ratio of static energy/dynamic energy. Results are not too numerous to be conclusive but indicate fair agreement in our calculations.

Furthermore, all steels tested have shown increases, to various degrees, in energy required to rupture in tension impact at −40° F as compared with the ambient temperature. In static tension, as is seen, the effect of lowered temperature is not constant, (note results on steel 7X9206), since again the experimental values for the required

Table 5—Comparison of Energy Absorption (Ft-Lb) of Static and Dynamic Specimens at Ambient and −40° F Temperatures

Note: "Location of break" is indicated as follows: *W* = in the weld, *HA* = in the heat-affected zone

		Base Metal				*Butt-welded material*							
		Ambient temperature		*−40° F temperature*		*Ambient temperature*				*−40° F temperature*			
Steel	*Gage length, in.*	*Static*	*Dynamic*	*Static*	*Dynamic*	*Static*		*Dynamic*		*Static*		*Dynamic*	
17-7	2	82	141.5	94	160	49	W	57.5	W	47.5	W	88	W
120,000 psi	1	54	62.5	...	63.5	38.5	W	32	W	..		58.5	W
T. S.,	1/4	27	25	...	25	18.5	W	16.5	W	..		22.5	W
Heat 26225	0.040	10	7	11.5	...	7	W	9	W	10	W	7.5	W
	0.040 outside					11.5	HA	7.5	W	11	HA	13	W
17-7	2	130	133	125	155	94	W	70	HA	70	W	117	W2, HA1
127,000 psi	1	85	80	82	90	42	W	36	HA	40	W	61	W
T. S.,	1/4	35	23	37	32	20	W	17W1	HA2	20	W	26	W
Heat 7X9206*	0.040	15	10	20	13	10	W	11	HA	11	W	15	HA
	0.040 outside					15	HA	9	W	20	HA	15	W
17-7	2	110	105.5	125.5	142	21.5	W	23.5	W	22	W	32	W
167,000 psi	1	59.5	65.5	...	78	22	W	24	W	..		32	W
T. S.,	1/4	24.5	22.5	...	26	17	W	20	W	..		24	W
Heat 20352	0.040	11	10	22.5	13	7	W	10	W	8.5	W	12	W
	0.040 outside					6	HA	10	W	16	HA	11	W
16-16-1	2	113	137	209	154	72	W	107	W	91	W	59	W
111,000 psi	1	71	79	122	72	40.5	W	47	W	48	W	48	W
T. S.,	1/4	31	21	42	...	18	W	20	W	21	W	17	W
Heat 8X7969	0.040	13	10	12	11	6	W	6	W	7	W	6	W
	0.040 outside					11	HA	10	W	14	HA	13	W

* Heat 7X9206 (127,000 psi). When failed in the heat-affected zone (butt welded, ambient, dynamic) the energy values are about 1/2 of those for base metal under similar conditions.

energy are governed by the tensile strength as well as ductility.

When the experimental values, as recorded directly from machine readings, are expressed in ft-lb *per unit volume* of the material that absorbed the energy (in this case per cubic inch), an entirely different result emerges, namely, lack of dependence of required energy upon gage length, except in cases of very small lengths already discussed.

The impact results at ambient and −40° F temperatures on each of the four parent metals, i.e., 17-7 (120,000 psi tensile strength) and 16-16-1 (111,000 psi tensile strength) are given in Table 4 gage lengths of 0.040, 1/4, 1 and 2 in. Tension impact energy results for base metal are also plotted in Fig. 17 for the various lengths. Elongation results (to be analyzed shortly) are shown in Fig. 18. It is to be noted that the elongation results are not reported on 0.040 in. gage specimens since these values always exceed "100%," obviously due to the inaccuracy attendant to measuring such small gage lengths.

The following observations can be made from these data:

1. Energy absorption is very nearly a constant value independent of gage lengths (between 1/4 and 2 in., incl.) of tests used in the investigation.

2. Results for 0.04-in. gage lengths, showing such high values, are unreliable because plastic deformation extended into portions of the specimen *outside* the gage length. Nevertheless, these results clearly show that brittleness is not the cause of low impact.

3. In all three steels of the chromium-nickel austenitic type, the higher the tensile strength (or the so-called "temper"), the better are the values for tension impact strength per unit volume when testing has been done at −40° F temperature (as compared with those at room temperature).

4. The chromium-manganese austenitic stainless steel shows no increase in tension impact as the test temperature is lowered to −40° F.

5. In the case of chromium-nickel steels, the permanent (plastic) deformation accompanying the impact tests is as a rule either equal to or somewhat greater at −40° F than at room temperature.

6. In the case of the chromium-manganese steel, permanent deformation at −40° F is lower than at ambient temperature.

Tension Impact Characteristics at Temperatures Below −40° F. It appeared desirable to extend the above studies to even lower temperatures than −40° F. Consequently, tests were carried out at −110 and −300° F, but on only two steels, a regular chromium-nickel stainless of 1/2 hard temper and the other a chromium-manganese stainless (heat 7X9206 with a tensile strength of 167,000 psi and heat 8X7969 with a tensile strength of 111,000 psi, respectively).

The gage lengths of the specimens were limited to two: 0.04 in. to see if such low temperatures will introduce embrittlement of this gage and a standard 2 in., since it was believed that the latter dimensions would at least suggest the effect of even lower tempera-

Table 6—Impact Results of Stainless Steels at −110 and −300° F

Steel	Spec. No.	Spec. gage length, in.	Temp of test, ° F	Energy, ft-lb, experimental	Elong, %	Energy, ft-lb/in.³, calculated
7X9206	1	0.04	−110°	15.3	...	23,700
7X9206	4	0.04	−110°	17.4	...	26,900
7X9206	9	2.06	−110°	164.0	34.0	4,900
7X9206	10	2.06	−110°	153.0	33.0	4,600
7X9206	3	0.04	−300°	26.0	...	39,800
7X9206	2	0.04	−300°	26.0	...	39,800
7X9206	11	2.06	−300°	164.0	30.0	4,930
7X9206	12	2.06	−300°	161.0	29.0	4,880
8X7969	15	0.04	−110°	14.3	...	24,500
8X7969	16	0.04	−110°	15.0	...	24,700
8X7969	23	2.07	−110°	157.0	34.0	5,040
8X7969	24	2.06	−110°	148.0	34.0	4,790
8X7969	17	0.04	−300°	12.0	...	19,420
8X7969	18	0.04	−300°	14.0	...	23,600
8X7969	25	2.06	−300°	182.0	35.0	5,880
8X7969	26	2.07	−300°	169.0	32.0	5,410

Table 7—Rupture Energy at Various Temperatures in Ft-Lb per Cu In.

	Temperature of tests							
	Ambient		−40° F		−110° F		−300° F	
Steel	Energy	Elong, %	Energy	Elong, %	Energy	Elong, %	Energy	Elong, %
7X9206	3930	34.0	4570	37.0	4750	33.5	4900	29.5
Heat 8X7969	4480	39.0	4970	37.0	4915	34.0	5645	33.5

Table 8—Static-Dynamic Energy Ratio of Base and Butt-Welded Materials at Ambient and −40° F Temperatures

Base Metal. Ratio = Static energy/Dynamic energy

Steel	Gage length, in.	Ambient temp ratio	−40° F temp ratio
17-7	2	0.58	0.59
120,000 psi	1	0.86	...
T. S.,	1/4	1.08	
Heat 20352			
17-7	2	0.97	0.81
127,000 psi	1	1.06	0.91
T. S.,	1/4	1.52	1.16
Heat 7X9206			
17-7	2	1.04	0.88
167,000 psi	1	0.91	...
T. S.,	1/4	1.09	...
Heat 26225			
16-16-1	2	0.82	1.36
111,000 psi	1	0.90	1.69
T. S.,	1/4	1.48	...
Heat 8X7969			

Table 9—Chemical Analysis and Mechanical Properties of Low-Alloy Steels Used

Table (A)		Table (B)	
Cor-Ten	Yoloy	Cor-Ten	Yoloy
0.16 max	0.15 max	50,000 (min), psi	50,000 (min), psi
0.90 max	0.75 max	70,000 (min), psi	70,000 (min), psi
0.10 max	0.10 max	22% (2 in.)	22% (2 in.)
0.30%	0.30%	0.075 in.	0.075 in.
0.30–0.60%	1.5–2.0%		
0.20–0.35%			
0.25–0.50%	0.75–1.25%		

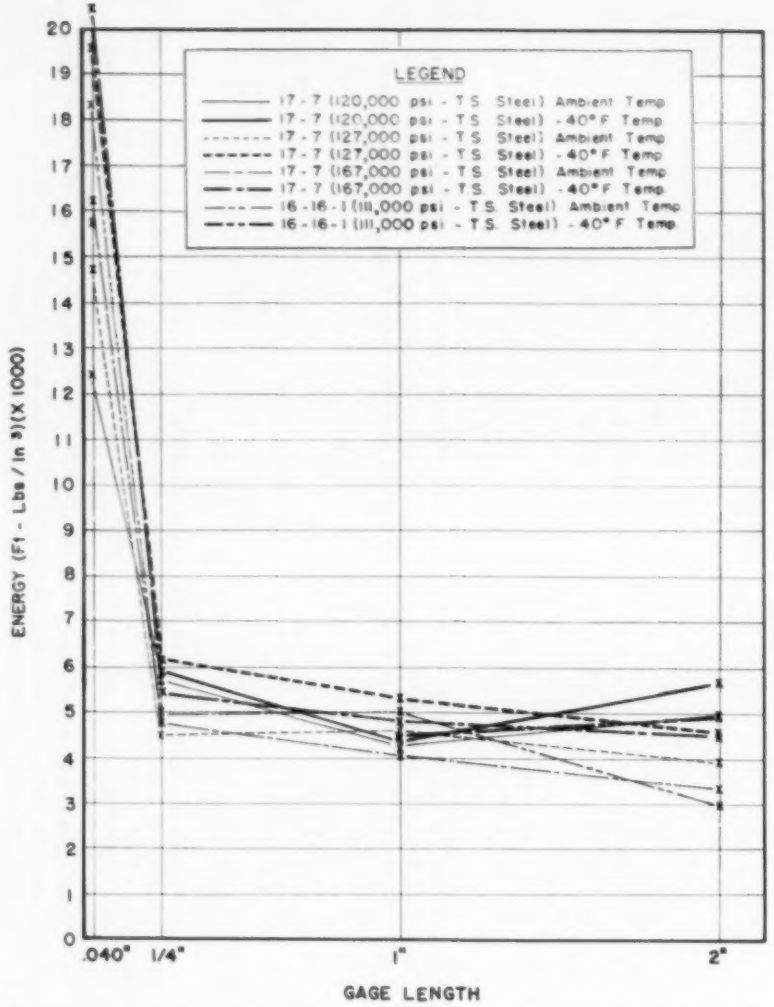


Fig. 17 Dynamic energy results of the base metal of the four steels tested at ambient and −40° F temperatures for the various gage lengths used

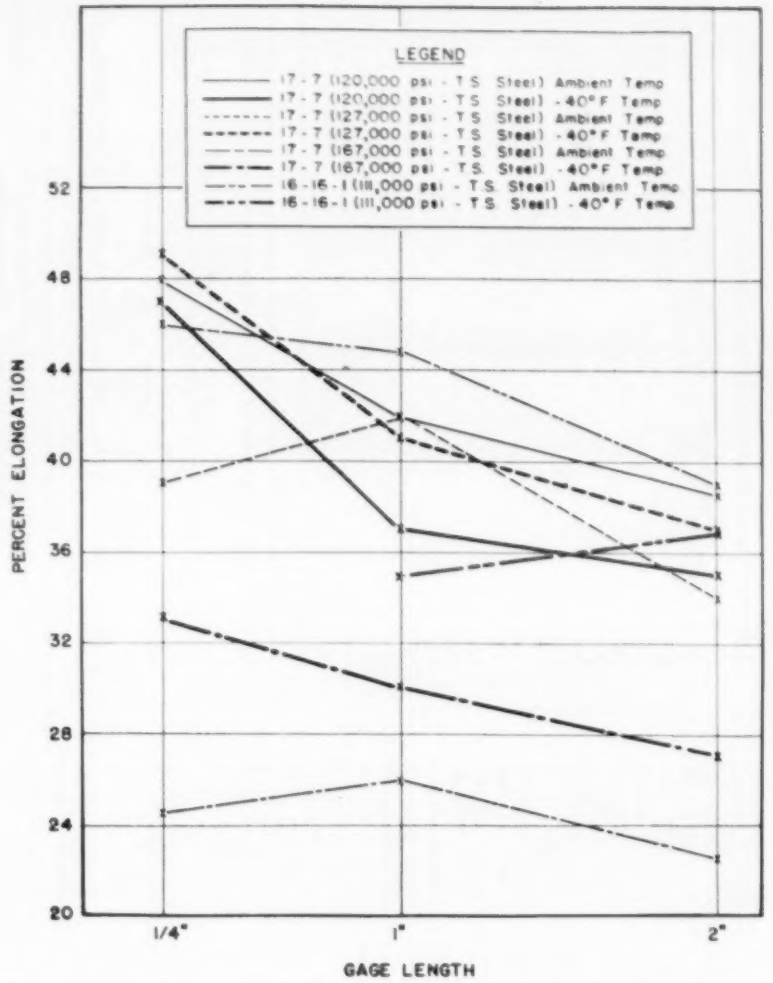

LEGEND
17 - 7 (120,000 psi - T.S. Steel) Ambient Temp
17 - 7 (120,000 psi - T.S. Steel) - 40° F Temp
17 - 7 (127,000 psi - T.S. Steel) Ambient Temp
17 - 7 (127,000 psi - T.S. Steel) - 40° F Temp
17 - 7 (167,000 psi - T.S. Steel) Ambient Temp
17 - 7 (167,000 psi - T.S. Steel) - 40° F Temp
16 - 16 - 1 (111,000 psi - T.S. Steel) Ambient Temp
16 - 16 - 1 (111,000 psi - T.S. Steel) - 40° F Temp
PERCENT ELONGATION
20
24
28
32
36
40
44
48
52
1/4"
1"
2"
GAGE LENGTH

Fig. 18 Elongation results of dynamic testing of base metal of the four steels tested at ambient and −40° F temperatures for the various gage lengths used (except 0.040 in.)

tures on the values for energy absorption.

The recorded (i.e., direct test results) ft-lb of energy as well as those calculated to give values per unit volume (ft-lb per cu in.) will be found in Table 6.

For ready comparison, the effect of lowering temperatures on the amount of energy required for rupture is summarized in Table 7 for specimens of "standard" gage length, i.e., 2 in. Similar effect on the shortest gage length will be discussed later.

It is evident that the effect of lowered temperatures is to increase the energy required for rupture. The significant thing is that at temperatures as low as liquid nitrogen, the ductility at fracture still remained quite high. There was no trace of what would be commonly called "brittle" fracture.

(*b*) *Impact Results at Ambient and −40° F Temperatures on Butt-Welded Materials.* The testing procedure for the butt-welded materials was the same as for the base metal. It should be emphasized that welding and subsequent machining of the butt-welded specimens were done with utmost care. When the samples were finished, the weld was flush with the base metal, the greatest difference in thickness being less than 0.002 in. on each side of the welded sample. All welds were X-rayed to assure freedom from cracks, porosity and inclusions. It is to be recorded that during testing all fractures (except for one steel, discussed later), took place in the weld metal. Although a greater scatter of results was noted compared to base metal results, it is believed that the cause of it was unavoidable due to inherent welding factors rather than due to a variation in dimensions. The test results are shown in Tables 4 and 5 for gage lengths of 0.040, 1/4, 1 and 2 in. Energy results are plotted in Fig. 19 for the various gage lengths.

Reference to Table 5 will show that even though samples of various gage length *broke in the welds* the ft-lb values, either in static or dynamic tests, are dependent upon gage length. Good examples of this comment would be 88 ft-lb for 2 in. and 58.5 ft-lb for 1-in. samples of Heat 26225, of 120,000 psi tensile strength. Obviously, then, some energy is utilized in deforming base metal and conclusion is inevitable that the weld has both strength and ductility to allow deformation of base metal to take place *prior* to the failure of the weld. As the tensile strength of the base metal is increased (Heat 20352), the strength of the weld is considerably lower by comparison, insufficient to cause appreciable deformation of base metal, and the dependence of energy values upon gage length large disappears.

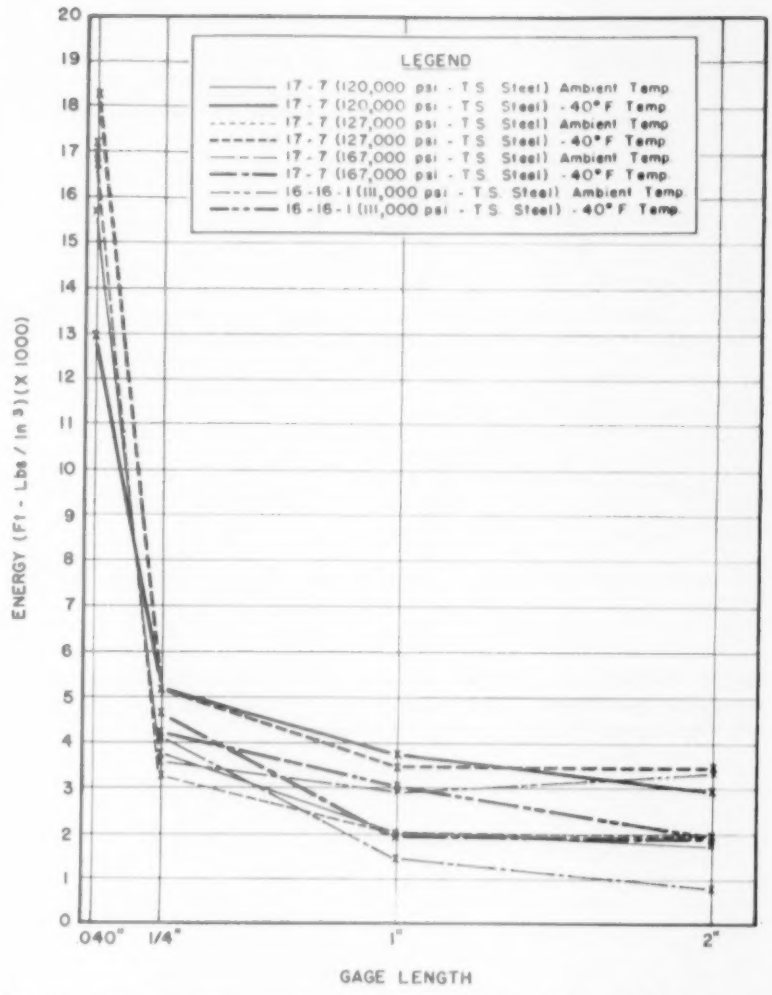


Fig. 19 Dynamic energy results of the butt-welded material of the four steels tested at ambient and −40° F temperatures for the various gage lengths used

The following observations can be made from these data.

1. In terms of dynamic strength, the welds are inferior to the parent metal by a factor as high as 2.5 or 3.

2. When the rupture occurred in the weld, the latter, as well as the base metal, show considerable ductility. In the case of rupture in the heat-affected zone, the ductility of the base metal was low, again indicating the effect of heat of welding on the properties of the base metal.

3. The impact (dynamic) strength of the welded chromium-nickel stainless steels is consistently greater at −40° F than at room temperature.

4. In the case of the chromium-manganese (16-16-1) steel, the situation is either reversed or the effect of temperature is negligible.

In some cases (notably Heat 7X9206 of 127,000 psi tensile strength) the failure took place in the heat-affected zone (reference-impact tests at ambient temperature) of the base metal. In such cases the experimental values for the energy are considerably lower than the same for the base metal (without welds). Thus, it is proper to assume that, during welding, weakening—through annealing by welding heat—has taken place in originally cold-worked material to such a degree that welds proper are stronger.

The experimental values obtained on a gage length of only 0.04 in. were already mentioned as unsuited for calculations because some dynamic energy was absorbed by the metal outside the gage length. The word "unsuited" is used in the sense that numerical values of the actual tests would be subject to too much error if related to volume. At the same time, the tests on such a small gage length, as to come near a notch effect—*note:* sharper notches are being investigated—clearly show that all steels under test show remarkable toughness and certainly would not be subject to brittle failure. Especially gratifying are the experimental

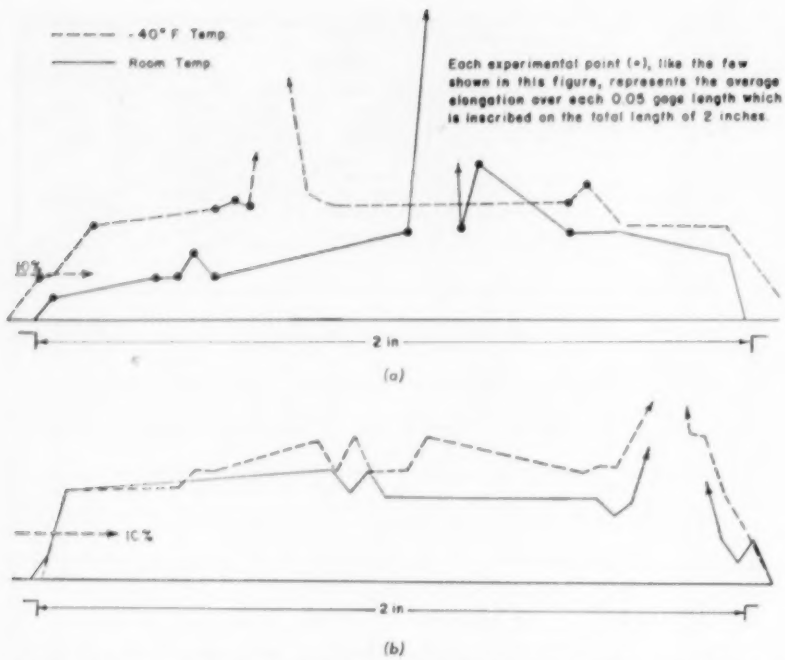

- 40° F Temp.
Room Temp.
Each experimental point (•), like the few shown in this figure, represents the average elongation over each 0.05 gage length which is inscribed on the total length of 2 inches.
10%
2 in
(a)
10%
2 in
(b)

Fig. 20—(a) Static testing of base metal of 17–7 (167,000 psi) stainless steel showing elongation measurements. (b) Impact testing of base metal of 17–7 (167,000 psi) stainless steel showing elongation measurements

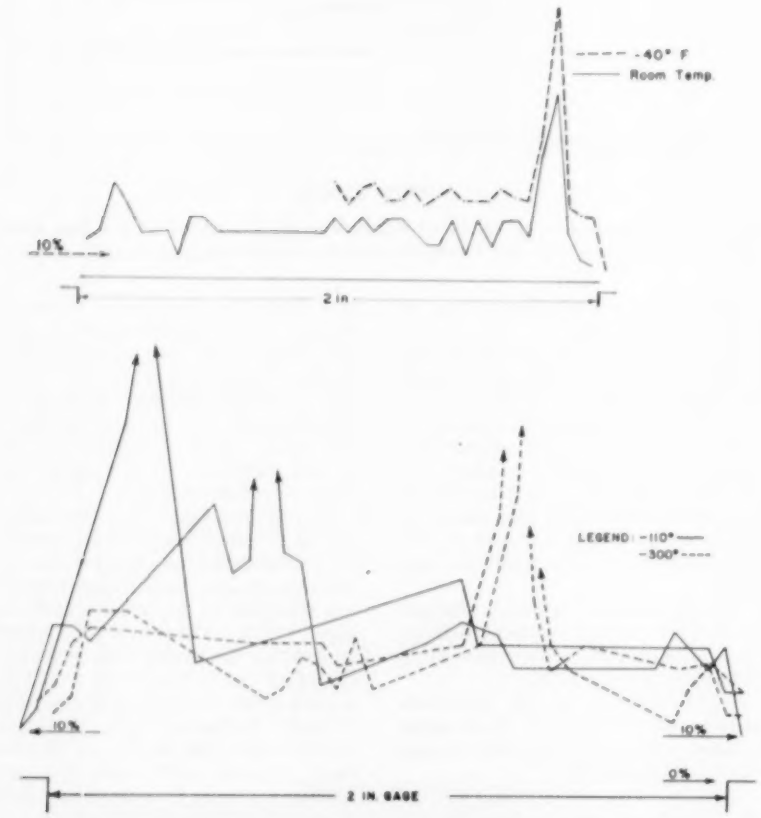


Fig. 21 Plot of percent elongation along gage length of specimens at each 0.05 in. length. Base metal (17–7) (127,000 psi). Temperatures are ambient, −40° F, −110° F and −300° F impact results

facts showing greater toughness at subzero temperatures evidenced by the uniformly greater ability for absorption of dynamic energy.

Again, it is to be noted that the heat of welding somewhat "damaged" the base metal in the heat-affected zone (at the ambient temperature of testing).

III. Studies of Distribution of Permanent Deformation (Elongation) Under Impact Testing

The adopted method of gridding the samples into squares only 0.05 in. apart and preserving the record of such grids before and after testing permitted a general study of the distribution of plastic "local" deformation (elongation on 0.05-in. gage length) over the selected gage lengths (on all) of the samples, i.e., 0.04, 1/4, 1, 2 and 4 in. (on some steels). Stainless steels of various levels of strength were experimented with at temperatures as low as −300° F.

The following discussion pertains to studies of samples of 2-in. gage length. Either shorter or longer samples (i.e., 1 or 4 in.) yielded similar facts.

(a) *Impact vs. Static Tests.* The studies of *static* tests showed that throughout the whole gage length from shoulder† to shoulder, the permanent stretch (ductility) is considerably above 10%, arbitrarily selected in these studies as a criterion of nonbrittle material* (Fig. 20). The same pattern of ductility is obtained when the same steel is tested in tension *impact* either at room or −40° F. It means that even at this level of strength (about 167,000 psi), the steel is capable of taking on considerable plastic flow before yielding to impact fracture: lower tensile strength steels, obviously, do equally well or better.

(b) *Influence of Very Low Temperatures.* Two stainless steels, one of standard analysis for this type of material (see Table 8) representing the so-called "1/4-hard" grade, and the other of the chromium-manganese analysis (found to be quite useful for constructional purposes) were similarly tested at −110 and −300° F, and their behavior was again studied in detail (see Figs. 21 and 22).

It is evident that even at these very low temperatures, the previously observed distribution of elongation is maintained. In fact, actual values for ductility throughout the sample are somewhat higher. The observed facts are important in appraising the reasons for recorded toughness and strengths of stainless steels.

It has been noted that regions immediately adjacent to the weld show decreased ductility. This is particularly true in the steel of the highest tensile strength that was investigated. Figure 23 shows the comparison between

* That is, the one which absorbs considerable dynamic or static energy before fracturing.

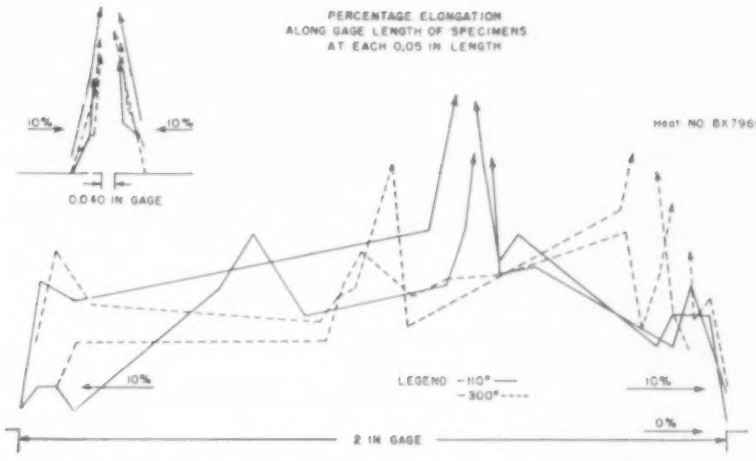


Fig. 22 Stainless steel impact tension test on base metal at −110 and −300° F temperatures

test results on "base metal" and "welded" samples. In steel of lower strength, this effect is practically absent (Fig. 24).

IV. Tests on Low-Alloy and Carbon Steels

Stainless austenitic steels, because of their metastable nature characteristic of many solid solutions at ambient temperatures, were shown in previous discussion to be rather unique in their ability to absorb impact energy, even at temperatures considerably below normal, and exhibit, at the instance of rupture, very considerable ductility (toughness).

A comparable series of tests on other ferrous materials appeared desirable. The purpose of these tests was not for the purpose of establishing numerical comparisons, but rather to establish whether other ferrous materials exhibit trends similar to those described for the stainless steels.

The compositions and mechanical properties of the chosen steels are given in Table 9.

The testing of these steels was carried out in the identical manner described in detail elsewhere. The graphic summary of the results will be found in Fig. 25, which shows the effect of lowered temperatures on rupture energy of low-alloy steels and how such energies compare with those experimentally developed for stainless steels. The advantages of stainless steels as a constructional material from the point of view of their ability to withstand impact stresses (dynamic) are obvious. It should be remembered, however, that the tests described in this presentation were conducted at only one velocity. Since higher velocities (than the one used in this investigation) are known to have detrimental effects upon the resistance to dynamically applied stresses,

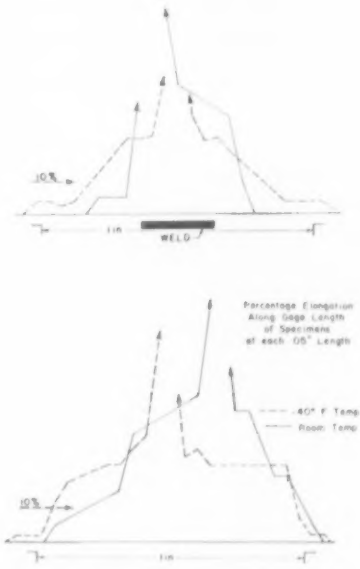


Fig. 23 Impact tests of 17–7 stainless steel (167,000 psi), base metal and butt welded

it may be very useful to learn what effects the velocities of impact testing may have on the rupture energies of stainless steels and other constructional materials.

Acknowledgment

The authors wish to express their gratitude to E. P. Gruca of the Pullman Standard Car Mfg. Co. for his valuable assistance in planning the experimental procedure and for his interest and advice in this work throughout its duration.

The necessary materials were made available through the kind cooperation of R. B. Gunia of United States Steel Corp., T. S. Fitch of the Washington Steel Corp., and the Pullman Standard Car Mfg. Co.

The authors are indebted to the International Nickel Co., Inc., in particular to T. H. Wickenden and F. L. LaQue, for the support of this work and for permission to publish the results.

D. W. McDowell, of the International Nickel Co., Inc., rendered considerable assistance in the preparation of this manuscript and the authors feel indebted to him.

References

1. Wattet and Lincoln, "Strength of Stainless Steel Structural Members as Function of Design," pub. Allegheny Ludlum Steel Corp.
2. Muhlenbruch, C. W., "A Tension Impact Test for Sheet Metals," *ASTM Bull.*, No. 196, p. 43 (TP 51) (February 1954).
3. Talbot and Krivobok, "Effect of Temperature on the Mechanical Properties, Characteristics and Processing of Austenitic Stainless Steels," *Proc. ASTM*, **50**, 895–930 (1950).

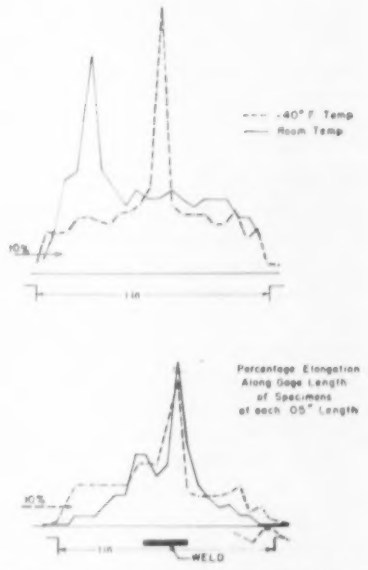


Fig. 24 Impact tests of 17–7 stainless steel (127,000 psi), base metal and butt welded

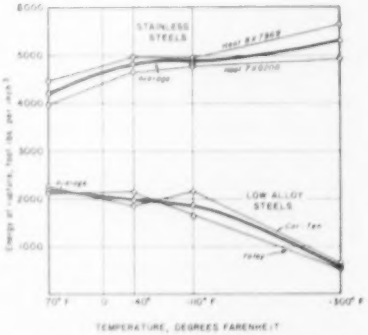


Fig. 25 Effect of lowered temperatures on rupture (impact) energy for low alloy and stainless steels

EFFECT OF PRETREATMENT OF MARTENSITE ON SUBSEQUENT GRAPHITIZATION AT 1200° F

Investigation shows that aluminum-deoxidized, eutectoid, plain carbon steel forms greatest number of graphite nodules at 1200° F if first pretreated at 800 or 1000° F

BY G. V. SMITH, E. J. DULIS, AND B. W. ROYLE

ABSTRACT. A martensitic eutectoid steel was found to form many more nodules of graphite at 1200° F if first exposed in the range 800–1000° F, suggesting a possible relation between the high susceptibility of martensite to graphitization and the transition from epsilon carbide to cementite (Fe_3C). The steel could be completely graphitized at 1200° F in 100 days, and showed an unusual reaction curve such that the rate slowed markedly after 5 days exposure.

Introduction

Since the occurrence over a decade ago of fracture in a welded steam pipe in a power generating station, it has become abundantly clear that graphitization, which in this instance led to failure, depends on microstructure. For example, previous study at the Fundamental Research Laboratory, United States Steel Corp.,[1] as well as elsewhere, has shown that steels graphitize much more rapidly from a martensitic than from a pearlitic microstructure. No fully satisfying explanation of this difference has been advanced. It has also been shown[1, 2] that, contrary to widely held belief, the efficacy of aluminum deoxidation in promoting susceptibility to graphitization cannot be attributed to a nucleating effect of the deoxidation products such as Al_2O_3 or AlN.

It was further shown in this previously reported work that nitrogen is an effective inhibiter of the inversion of Fe_3C to graphite and ferrite, and that the role of aluminum deoxidation is, in part at least, an indirect one involving the scavenging of nitrogen. Although the results were perhaps not completely convincing, they also seemed to preclude any direct role for aluminum inasmuch as it was observed that: (1) a purified Fe-C alloy readily graphitized in the absence of aluminum, whereas graphitization was completely inhibited in the presence of about 0.03% nitrogen; and (2) graphitization was inhibited in commercial steels when the amount of uncombined N in the as-quenched condition was increased by heat treatments that altered the amount of uncombined aluminum inconsequentially.

G. V. Smith, E. J. Dulis and B. W. Royle are associated with Fundamental Research Laboratory, United States Steel Corp., Kearny, N. J.

The experiments reported here were undertaken to elucidate the matter of the susceptibility of the martensitic microstructure as well as to shed further light on the nucleation of graphite. It seems possible that graphite nuclei may originate in the tempered martensite structure at the time of breakdown of the tetragonal lattice. Moreover, it is now known[3, 4] that when martensite is tempered at low temperatures, it is not orthorhombic iron-carbide (cementite) but rather close-packed hexagonal iron-carbide (epsilon) which precipitates. The epsilon carbide has been reported to have the approximate composition $Fe_{2.4}C$, and is replaced by orthorhombic carbide (cementite) at higher tempering temperatures. The exact temperature of transformation is not known and, indeed, reported temperatures vary considerably,[6, 7] depending in particular on the tempering time. On the basis of the reported data, it seems probable that in the short times experienced in continuous heating for tempering, epsilon might exist transiently at temperatures higher than 700° F. Hence, it appeared possible that the greater susceptibility of the martensitic structure to graphitization might be associated with this carbide transition.

Moreover, since $Fe_{2.4}C$ has a higher carbon content than Fe_3C it appeared possible that the "excess" carbon of the former phase might serve as graphite nuclei, especially if the steel were held long enough in the transition temperature range so that these nuclei could grow to a size sufficiently large to be stable at higher temperatures where graphitization heat treatments are conventionally conducted. However, recent electron microscope evidence[7] indicates that the transformation from epsilon to cementite does not proceed *in situ*, but rather by separate processes of solution of epsilon, and nucleation and growth of cementite.

Material and Procedures

The composition of the steel studied is as follows:

C, %	0.79	Ti, %	0.01
Mn, %	0.62	Al, %	0.069
P, %	0.011	Al_2O_3, %	0.004

S, %	0.025	V, %	0.00
Si, %	0.23	Cu, %	0.03
Ni, %	0.02	Zr, %	0.01
Cr, %	0.02	N, %	0.005
Mo, %	0.00		

Samples approximately $^1/_4$ in. thick were brine-quenched after austenitizing at 1600° F for $^1/_2$ hr, then tempered 2 hr at 400, 600, 800, 1000, 1200 or 1300° F, and finally heated at 1200° F for 5 and 10 days. An additional sample was tempered for 19 hr at 400° F. The samples were then sectioned and examined microscopically in a region remote from possible surface effects, such as previously noted.[1] Inasmuch as little difference was noted between the degree of graphitization in samples exposed for 5 or 10 days, the authors were led to wonder whether the breakdown of carbide ceased before completion of the reaction, as might result, for example, from concentration of manganese in the carbide. Accordingly an additional experiment was conducted in which samples quenched from 1600° F were heated directly at 1200° F for up to 100 days.

Results and Discussion

The results of the "pretempering" experiment are summarized in the photomicrographs of Fig. 1. Whereas little difference will be noted between the samples pretempered at the graphitizing temperature, 1200° F, and those pretempered at 400 or 600° F, before exposure at 1200° F, there is clearly a significant increase in the number of graphite nodules in the samples pretempered at either 800 or 1000° F. In contrast, pretempering at 1300° F results in definitely fewer nodules.

The temperature range 800 to 1000° F is one in which orthorhombic cementite (Fe_3C) develops rapidly,[6, 7] and if it is assumed that the transitional epsilon carbide precipitates first, either during heating to 800–1000° F or transiently at 800–1000° F, as seems entirely possible, the results are not a variance with the hypothesis which led to the experiment, though they do not prove it. If the formation of graphite is intimately interrelated to the carbide transition, the relation is presumably attributable to the "free" carbon released when the epsilon carbide dissolves in alpha preparatory to re-precipitating as orthorhombic carbide. Moreover, the greater susceptibility of the martensitic microstructure in relation to pearlite microstructures is understandable, inasmuch as the carbide in pearlite presumably forms directly as Fe_3C.

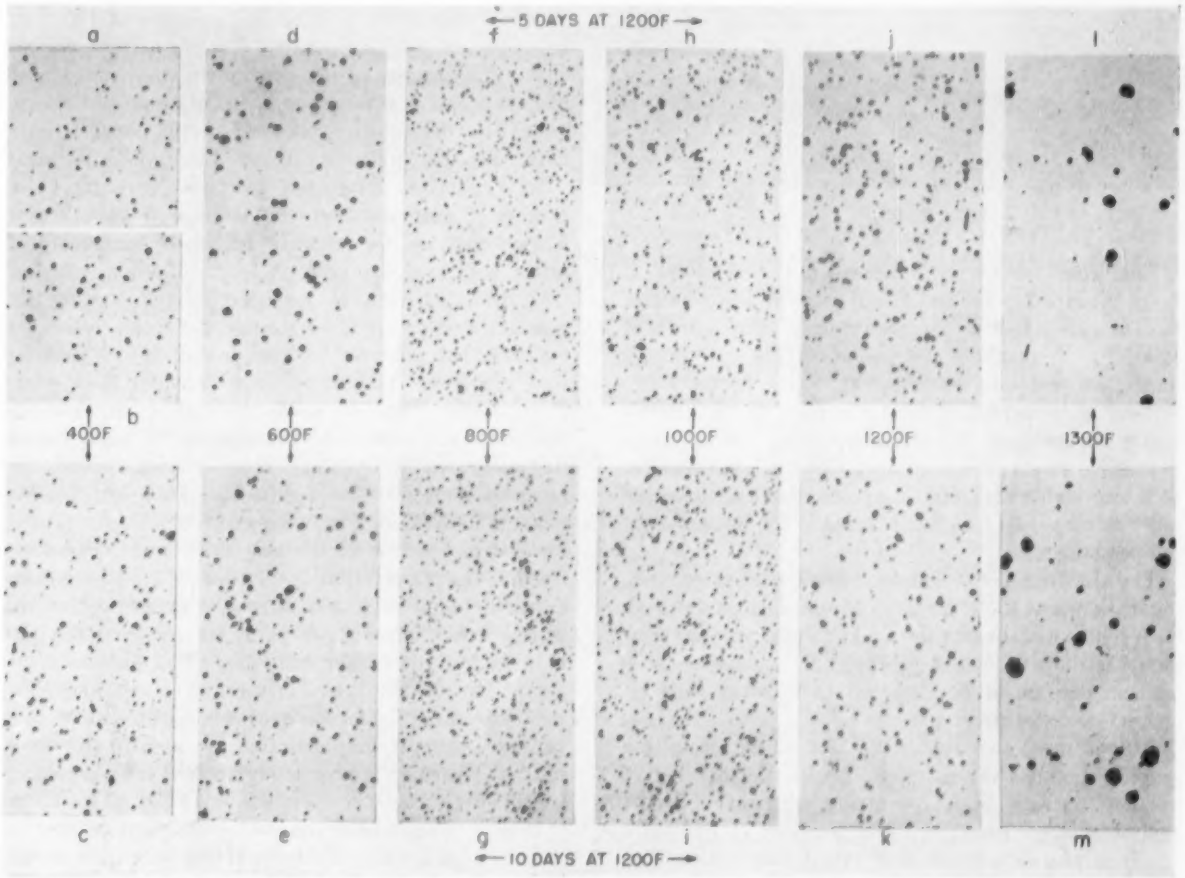


Fig. 1. Specimens brine quenched from 1600° F, tempered at temperatures indicated for 2 hr (except *b* which was tempered for 19 hr), then graphitized at 1200° F for 5 and 10 days. Unetched. X 100. (Reduced by 25% upon reproduction)

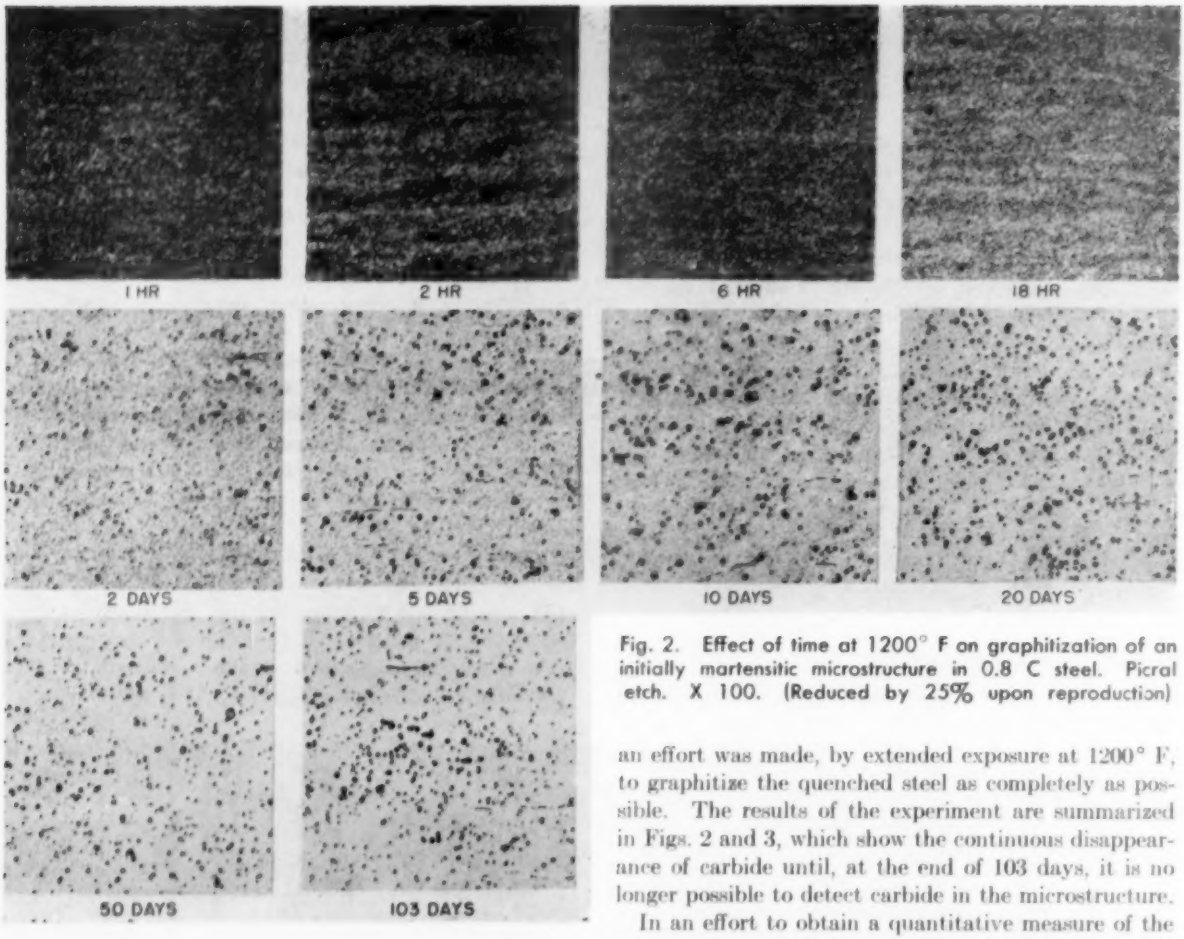


Fig. 2. Effect of time at 1200° F on graphitization of an initially martensitic microstructure in 0.8 C steel. Picral etch. X 100. (Reduced by 25% upon reproduction)

The "free" carbon nuclei formed in the 800–1000° F range presumably are stable and grow in 2 hr to a size that is also stable at the graphitizing temperature of 1200° F. Presumably the epsilon carbide that formed during tempering at 400 and 600° F also forms "free" carbon on transforming during heating to the graphitizing temperature, but these nuclei do not in many cases have ample time to grow, during the rapid heating, to a size stable at 1200° F. Consequently, there are more stable nuclei for pretempering in the intermediate temperature range.

The small number of nodules formed when pretempering was done at 1300° F might be explained as resulting from solution of some of the nuclei formed at lower temperature during heating to 1300° F, since the stable nucleus size would be expected to increase with increased temperature.

It is of interest to note in Fig. 1 that the size of the graphite nodules varies inversely with the number of nodules, as has been repeatedly observed in past experiments, for example, those described in Reference 1. It is also of interest that visual observation does not suggest much, if any, difference in the quantity of graphite after 10 days compared to 5 days. This unexpected observation led to the experiment in which an effort was made, by extended exposure at 1200° F, to graphitize the quenched steel as completely as possible. The results of the experiment are summarized in Figs. 2 and 3, which show the continuous disappearance of carbide until, at the end of 103 days, it is no longer possible to detect carbide in the microstructure.

In an effort to obtain a quantitative measure of the process of graphitization, the samples of Figs. 2 and 3 were analyzed for graphitic carbon by dissolving in nitric acid (specific gravity 1.20), filtering, washing with dilute hydrochloric acid, drying and igniting the residue; analysis was also made for total carbon to confirm that only an inconsequental decarburization had occurred. The results are depicted in Fig. 4. With the exception of the datum for 103 days, which was checked and rechecked, and which is clearly out of line with the microscopic observations, the results are consistent with the results of Figs. 2 and 3. No possible explanation for the breakdown of the analytical method in the case of the 103-day sample can be offered. The plateau that develops after 5 days exposure is attributed to a decreased rate of graphitization resulting from the concentration of manganese in the carbide during the earlier exposure. The plateau after 5 days explains how it could appear in Fig. 1 that graphitization might have come to a cessation after this period. Actually graphitization proceeds in this steel until the carbide is completely converted to graphite, Fig. 3.

It is of interest from the nucleation point of view to note in Figs. 2 and 3, that nucleation is continuous, at least until the late stages of graphitization, whereas growth seems to slow markedly or to cease, as judged from the visual observation that the graphite nodules

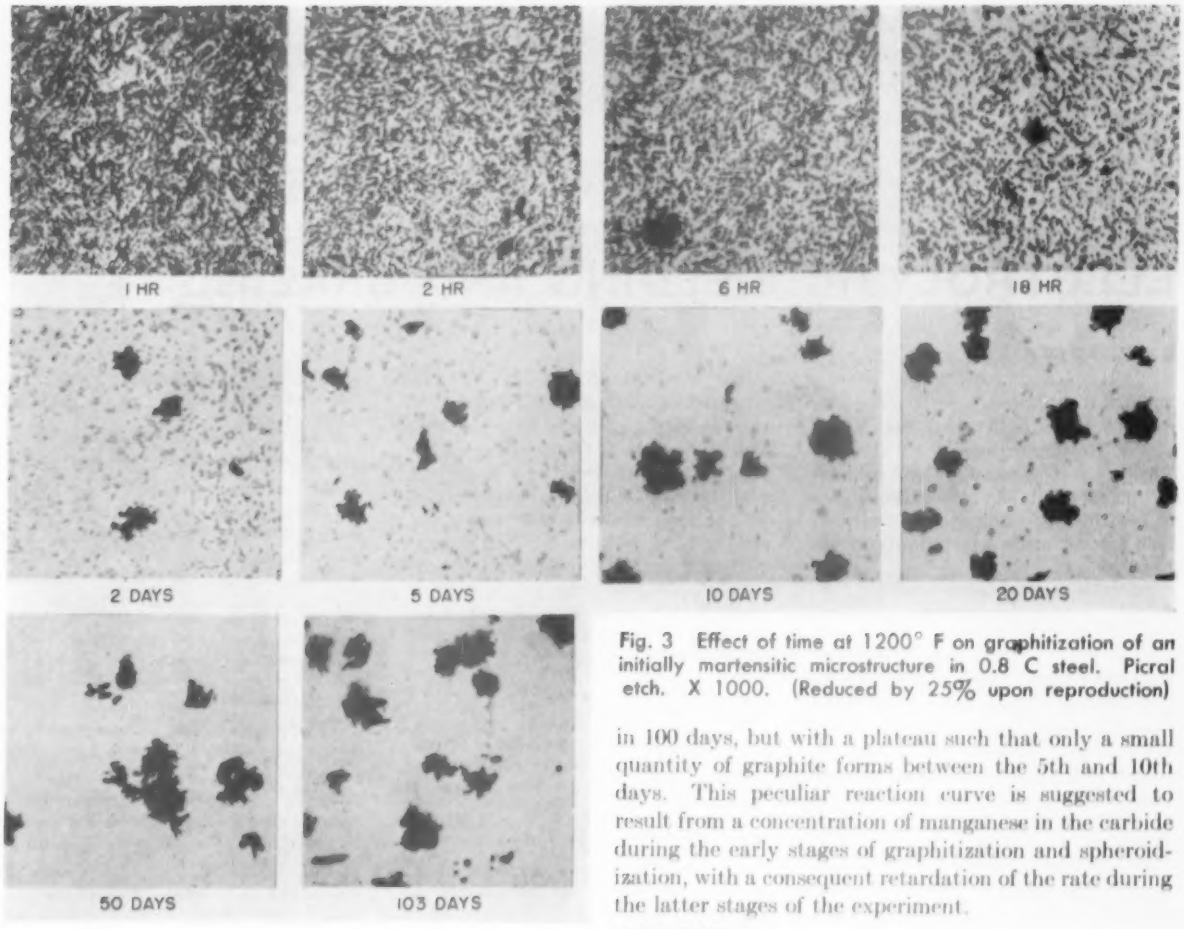


Fig. 3 Effect of time at 1200° F on graphitization of an initially martensitic microstructure in 0.8 C steel. Picral etch. X 1000. (Reduced by 25% upon reproduction)

do not appear to enlarge much beyond 5 days. In other words, there is not a limited number of nuclei which become exhausted with time.

Summary

Samples of an aluminum-deoxidized, eutectoid, plain carbon steel were quenched from 1600° F, then pretreated at 400, 600, 800, 1000, 1200 and 1300° F before graphitizing at 1200° F for 5 and 10 days. The greatest number of graphite nodules appeared in the samples pretreated at 800 or 1000° F, in support of the hypothesis that the greater susceptibility to graphitization of the martensitic microstructure is in part associated with the change from epsilon carbide to cementite; the number of nodules in the samples pretreated at either 400 or 600° F was not dissimilar to that in the sample treated directly at 1200° F, and the number in the sample pretreated at 1300° F was significantly smaller.

Since little difference was observed in the amount of graphite developed at 5 and at 10 days, an additional experiment was conducted to investigate the effect of time, and to determine whether complete graphitization could be effected if the exposure were sufficiently prolonged. The results of this experiment showed a continuing conversion to graphite, approaching 100% in 100 days, but with a plateau such that only a small quantity of graphite forms between the 5th and 10th days. This peculiar reaction curve is suggested to result from a concentration of manganese in the carbide during the early stages of graphitization and spheroidization, with a consequent retardation of the rate during the latter stages of the experiment.

Addendum

After completion of the authors' work, a paper by Hultgren and Edström,[8] on somewhat related work, was brought to their attention. These investigators observed that the number of graphite particles in malleable cast iron was greatly increased if the iron were quenched to form martensite; and further that the number of graphite nodules was increased by slow

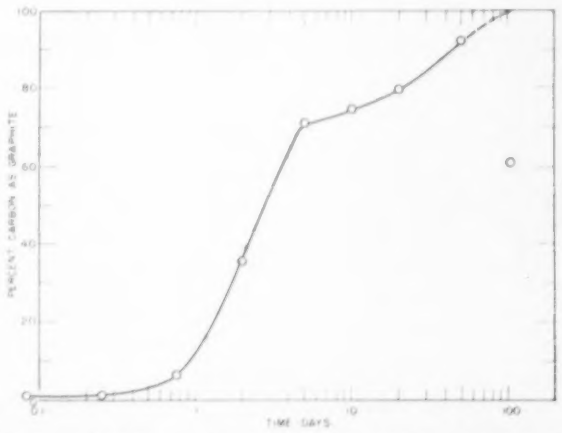


Fig. 4 Variation of quantity of graphite, determined analytically, with time at 1200° F. The 103-day datum is erroneous, for unknown reason

heating through the range 750 to 1200° F and by holding for a short period at 1110 to 1200° F prior to graphitizing at higher temperature, either above or below A_1.

References

1. Smith, G. V., MacMillan, J. A., and Dulis, E. J., "Some Aspects of Graphitization in Steel," *Trans. ASM*, **43**, 692–711 (1951).
2. Dulis, E. J., and Smith, G. V., "Rates of Aluminum and Nitrogen in Graphitization," *Ibid.*, **46**, 1318–1330 (1954).
3. Heidenreich, R. D., Sturkey, L., and Woods, W. L., "Investigation of Secondary Phases in Alloys by Electron Diffraction and the Electron Microscope," *Jnl. Appl. Phys.*, **17**, 127 (1946).
4. Jack, K. H., Discussion of "Electron Microscope Study of Quenched and Tempered Steel," *Jnl. Iron Steel Inst.*, **166**, 17–18 (1950); also *op. cit.*, **169**, 26 (1951).
5. Roberts, C. S., Averbach, B. L., and Cohen, M., "The Mechanism and Kinetics of the First Stage of Tempering," *Trans. ASM*, **45**, 576 (1953).
6. Antia, D. P., Fletcher, S. G., and Cohen, M., "Structural Changes During the Tempering of High Carbon Steel," *Ibid.*, **32**, 290 (1944).
7. Lement, B. S., Averbach, B. L., and Cohen, M., "Microstructural Changes on Tempering Iron-Carbon Alloys," *Ibid.*, **46**, 851 (1954).
8. Hultgren, A., and Edström, O., "Grafitbildning Vid Upphettning Av Martensit," *Jernkontorets Annaler*, **126**, 83–107 (1942).

ELECTROLYTIC WELDING AND BRAZING

BY P. ZUFFA

Successful experiments with electrolytic welding have been conducted in the Power Research Institute in Prague. The process is especially useful for nonferrous metals. The physical principles of electrolytic heating will be discussed first, after which some applications will be described.

A still electrode is immersed in a 10 to 15% aqueous solution of sodium carbonate. An iron beaker may be used as anode (Fig. 1). The area of the submerged cathode is 0.31 sq in. The submerged area of the anode should be at least 0.47 sq in. Three stages occur as the voltage is increased slowly.

1. Electrolysis. The current through the electrolyte (Fig. 2) is given by $i = (E - e)/R$, where R is the resistance of the electrolyte in ohms, E is the voltage between electrodes and e is the polarizing voltage (1.4 to 1.6 volts). The cathode is not heated but becomes coated with hydrogen.

2. As the voltage is increased (Fig. 3) electrolytic intermittance sets in. The current is $i = (E - e)/(R + r)$, where r is the variable resistance of narrow electrolyte bridges which alternately pass current and evaporate by Joule heating and prevent passage of current. The voltage is not high enough to break down the sheath of gas on the cathode. The temperature of the cathode rises, but most of the energy is consumed in the electrolyte, as the voltage is raised.

3. The cathode temperature reaches 374° C. The electrolyte no longer can cool the cathode because it is insulated by a continuous sheath of hydrogen and steam. The cathode becomes fluorescent as a result of a multitude of tiny discharges through the gas layer from electrolyte to cathode. The gas layer acts as a condenser, the charging current (Fig. 4), being

$$i = \frac{E - e}{R + X}\left(1 + \frac{X}{R}k - \frac{1}{CX}\left(1 + \frac{X}{C}\right)t\right)$$

where i = instantaneous value of current at time t, and X is the resistance of condenser C, the capacitance of which is

$$C = k\,\frac{S}{4\pi a}$$

a = the thickness of the layer of gas (0.0003–0.016 cm)

k = dielectric constant of the gas layer on the cathode

S = area of cathode submerged in the electrolyte

The cathode is bombarded by hydrogen ions, which release their kinetic energy to the cathode and heat it. The useful thermal effect is $Q = n\,(E - RI)I$

I = current in circuit

E = voltage between cathode and anode

R = resistance of electrolyte

RI = voltage drop in electrolyte

n = efficiency of heating, which varies from 30 to 40%.

The cathode and anode must be separated so as to prevent arcing and the cathode current density should be 5 amp/cm². The area of the anode should be at least 50% larger than the area of the cathode. The hydrostatic pressure of the electrolyte should not exceed ¾ to 1 ¼ in.

The electrolytic process is used to weld thermocouple wires 0.002 to ⅛ in. diameter. The wires are twisted together and made the cathode. The voltage is 80 to 220 v depending on diameter. A globule of molten metal forms at the tip, whereupon the current is switched off. The following combinations have been welded: nickel to Nichrome, iron to Constantan, molybdenum to iron. Pressure welding also can be used. The ends of the wires are heated until molten, then are pressed together. The current is less than 1% of that required for resistance welding.

Abstract of "Elektrické zváranie, spájkovanie a ohrievanie v elektrolyte," published in *Zváranie*, **3**, 304–308 (1954). (Prepared by Dr. G. E. Claussen.)

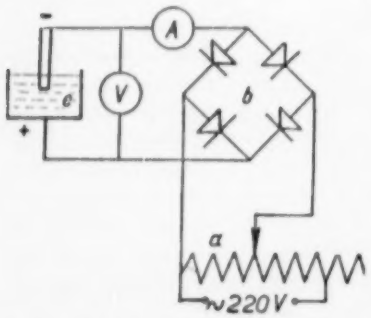


Fig. 1 The electrolytic welding circuit. *a* = auto transformer *b* = dry rectifier

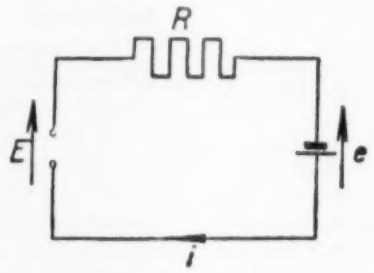


Fig. 2 Current and voltage in the circuit

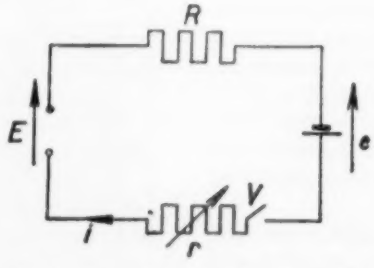


Fig. 3 Second stage of heating. The cathode is coated completely with gas. Small bridges of electrolyte form and vaporize. The bridges are shown schematically as variable resistance *r* and switch *v*

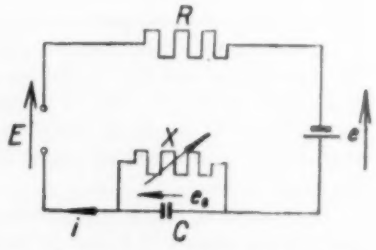


Fig. 4 Third stage of heating. The cathode is entirely surrounded by hydrogen and is above 374° C. The system: electrode-hydrogen-electrolyte is represented schematically by condenser C and resistance X

EFFECTS OF INTERSTITIAL ELEMENTS ON WELDABILITY OF TITANIUM ALLOY SHEET—PART 1

Three interstitial elements, carbon, nitrogen and oxygen, have been found to impair the weldability of titanium alloy sheet under some conditions

BY H. M. MEYER

ABSTRACT. Three interstitial elements, carbon, nitrogen and oxygen, impair the weldability of titanium alloy sheet. To quantitatively evaluate their effects, three typical base alloys containing small, intentional additions were welded. The alloys were:

a binary α alloy: 5% Al–Ti,
a ternary alloy containing an α and a β strengthening element: 7% Al–3% Mo–Ti, and
a binary β alloy: 25% V–Ti.

Weldability was to be determined essentially by bend ductility, while other mechanical properties of pilot and weldment were also investigated. Typical pre- and post-heat treatment cycles were to be selected for each individual alloy and interstitial addition to establish trends for restoring ductility, or strength, or a combination of both.

In the introductory Section I, methods of preparation, treatment and testing of the alloy sheet are described. Sections II, III and IV report on the mechanical properties of weldments in the three base alloys.*

Limits of addition to 5Al–Ti proved to be 0.20% for carbon, 0.18% for nitrogen and 0.25% for oxygen. No general pattern emerged for 7Al–3Mo–Ti; 0.15% O_2 yields strong, ductile microstructures in the post annealed weld zones. The 25V–Ti alloy showed little effect for carbon additions. Nitrogen produced erratic ductility results; oxygen bearing as-welded sheet was strong and ductile.

Side developments were the production of workable, weldable 8Al–Ti. Also 15V–Ti displayed an unorthodox, but promising response to low-temperature isothermal anneals.

Microstructures were methodically used to explain the mechanical properties of the welded zones, and several microstructural phenomena were uncovered.

Hardness was not a satisfactory indicator of brittleness in weld zones; it was, however, of good use for controlling the contamination of α alloy.

Interstitial elements in titanium alloy sheet weldments are harmful; where possible, limits of usefulness have been described. The fundamental study should help to enlarge and clarify the range of weldable titanium-alloy compositions. Heat treatments that will restore ductility after embrittlement by the welding cycle are described in terms of individual phase relationships.

I. Introduction

Most titanium is produced by the Kroll process which leaves in it some non-metallic impurities; their amount will be reduced eventually as it was in the case of the "older" metals—at increased costs. Already titanium has the handicap of high price ($3.95 per lb); therefore, wider consumption of slightly impure, so-called "commercially pure," sponge is essential for its industrial future.

This study contributes to the question: how do the impurities affect weldability? It is known that they can be tolerated in low-strength, unalloyed titanium; however, medium and high-strength titanium alloys which are paramount for future applications grow sensitive to weld brittleness. The causes of embrittlement vary, but eventually can be reduced to the foreign atoms which either substitute for titanium in the crystallographic lattice or lodge in its interstices. This study's first year dealt with the substitutional metallic elements and with the correlation of mechanical weld properties with thermal history and microstructure[1,2]; quantitative, comparable data for three typical titanium systems were made available to designers of metal parts which they might want to replace by titanium alloys. The second year of the study focuses on the non-metallic, interstitial elements carbon, nitrogen and oxygen† of which a few tenths of a percent were added to assess their effect on weldability.

(1) Selection of Titanium Base Alloys

Titanium transforms from body centered cubic β phase on cooling to closepacked hexagonal α phase at 1625°F. Alloying elements either raise or lower the transformation temperature and can, thus, be divided into α and β strengtheners; of the three base alloys selected for this study:

One is a binary α system: titanium-aluminum,
One is a ternary alloy containing an α and a β strengthener: titanium-aluminum-molybdenum, and
One is a binary β system: titanium-vanadium.

Aluminum is represented twice because it is the best metallic strengthener as shown by the widening α field in the phase diagram of Fig. 1.[3] The addition of aluminum is limited by the practical difficulty of deforming compositions of over 7% aluminum. During the study's first year alloys with 5 and 8% were tested among others; 5Al–Ti was ductile and weldable while 8Al–Ti proved brittle in welded and pilot (unwelded) condition. It was to be determined whether 8Al–Ti could be made ductile and weldable, and whether interstitial additions to 5Al–Ti would cause microstructural alterations and embrittlement. No interstitial additions were contemplated to the 8% and 7% Al–Ti. Since the interstitial solubility is known to be higher in α than in β titanium, a possible way of reducing embrittlement in the borderline 7Al–Ti was the incorporation of a β-isomorphous element. Molybdenum was selected and 3% added; the partial

H. M. Meyer was Research Metallurgist, Metals Research Department, Armour Research Foundation of Illinois Institute of Technology, Chicago, Ill., where this study was carried out, and is now Chief, Metals Research Branch, Watertown Arsenal Laboratory, Watertown, Mass.

Presented at the 1954 National Fall Meeting, held in Chicago, Ill., Nov. 1–5, 1954. Sponsored by the Materials Laboratory, Wright Air Development Center, under Contract No. AF 33(616)-206.

* Sections I and II form Part 1, while Sections III and IV will appear as Part 2 in a subsequent issue of the Welding Research Supplement. This abstract covers complete study.

† Their combined influence, and the effect of hydrogen are being investigated at present.

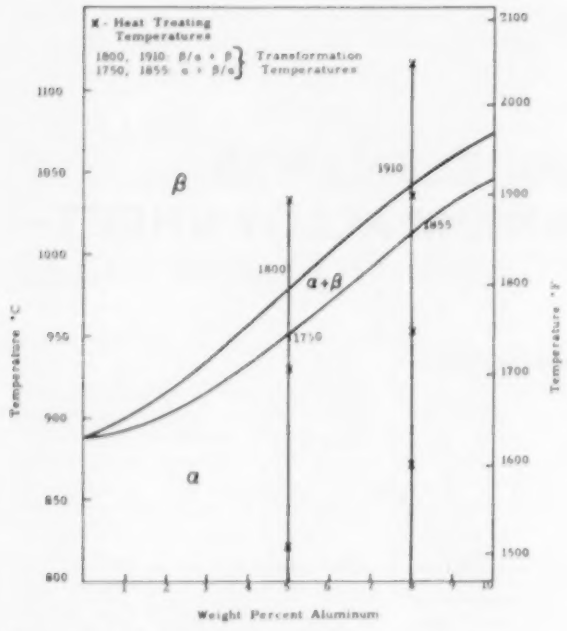


Fig. 1 Partial phase diagram Ti–Al

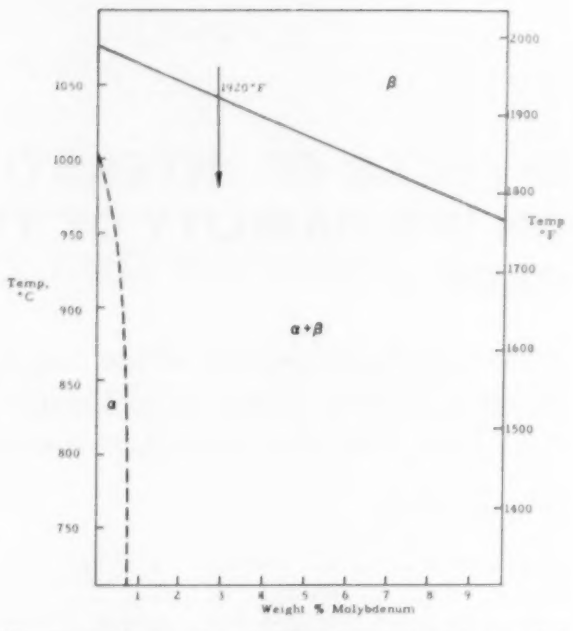


Fig. 2 Vertical section at 7% Al content of the partial Ti–Al–Mo system

phase diagram of 7Al–3Mo–Ti is shown in Fig. 2.[4] Molybdenum, however, was not used for the third base alloy, since 30 Mo–Ti had not produced truly β stable weld structures, and vanadium chosen instead. The practical interest in all β alloy stems from the advantage of ductile all-β structures in all the weld zones; it would be the counterpart of the weldable all-α alloy of the 5Al–Ti type. Vanadium was alloyed in amounts from 4 to 30%; the 15 and 25% compositions as the most likely to be metastable were subject to methodical heat treating cycles. Although none of the vanadium alloys eventually proved β stable—since either β' brittleness developed or α' precipitated—Ti–V alloys are ductile under many as-welded and postheat-treated conditions. Therefore, it was decided to investigate the influence of the same small interstitial amounts added to 5Al–Ti also on the 25V–Ti alloy. The phase diagram of Fig. 3[3] shows a sloping $\beta/\alpha + \beta$ boundary, a wide $\alpha + \beta$ field and a restricted α field. In this it resembles the partial diagram of Fig. 2; in both systems, the metal affected by the welding cycle is temporarily in the β field while the base metal never went beyond the $\alpha + \beta$ field. Since the thermal history of the weld zones is different, their microstructures are not uniform and frequently cause deterioration of service performance; it is known from steel metallurgy that heat treatments are sometimes helpful in restoring mechanical weld properties.

(2) Heat Treating Cycles

Weldments which are ductile in the as-welded state are preferable to those made ductile by postheat treatment, as also would be a sheet made weldable by preheat treatment at the manufacturer's plant. Previous work, however, has made it improbable that heat treatment prior to the welding operation will solve the weldability problem, and non-heattreatable alloys, ductile in the as-welded state, are confined to low-alloy compositions of moderate strength, to all-α alloys and to exceptional systems like Ti–6Al–4V. The welding engineer's need for better understanding of weld brittleness in medium and high-strength titanium alloys arises from this experience. Heat treatment to improve non-equilibrium structures in the weld zones depends on alloy system, composition and interstitial content, and no general approach is available.

The four types of heat treating cycles applied were to serve either of two purposes: the continuation to completion of any phase transformation caused by welding, or the homogenization of the various zone structures by re-solution treatment. The heat treatments were modified to clarify the relationship of microstructure to performance, and to improve ductility or increase strength, or both; however, no attempt was made to achieve peak performance of the weldments.

(*a*) Step-quench type treatment. The weld zones are solution treated for homogenization in the high-temperature field from which they are quenched into a lead bath for isothermal anneal producing a more stable or more satisfactory, strong and ductile, structure.

(*b*) Simple-reheat type treatment.

Table 1—Setting of Welding Variables for Al–Ti Base Sheet

Alloying elements (wt, %)				*Current*	*Travel speed,*
Al	*C*	*N*	*O*	*amp*	*in./min*
5	...	...	...	122	24 8
5	0 1	...	...	110–132	21 5
5	0 2	...	...	130	19 0
5	0 3	...	...	122	21 5–23 5
5	0 4	...	...	110	23 5
5	...	0 1	...	128–130	21 5–24 8
5	...	0 2	...	122–130	21 5–24 8
5	...	0 3	...	136	19 0
5	...	...	0 1	158*	20 3–21 5
5	...	...	0 2	120–122	19 0–20 3
5	...	...	0 3	140	24 8
8	...	...	...	122–130	19 0

* Welded with $^3/_{32}$-in. diam electrode.

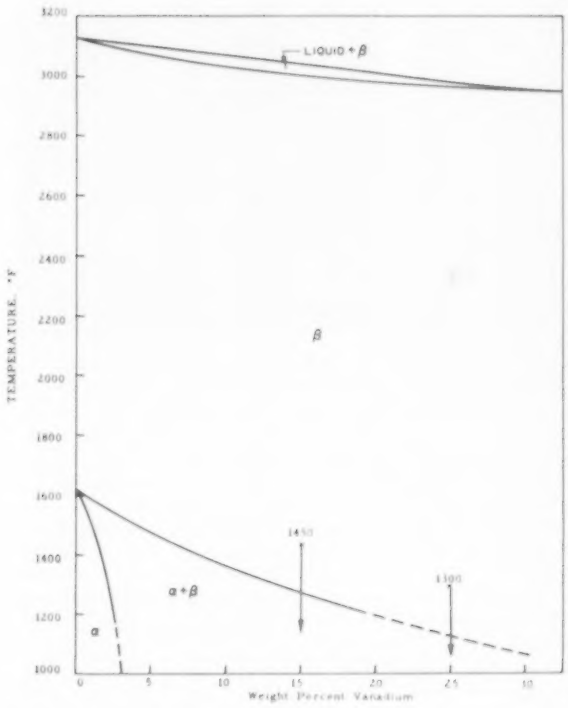


Fig. 3 Partial Ti–V phase diagram

Fig. 5 Bending jig with five interchangeable sets of rolls and mandrels

The solution treatment is omitted and merely an α or $\alpha + \beta$ anneal is applied so that the phase transformation interrupted at the end of the welding cycle can proceed to better structures.

(*c*) Double-isothermal type treatment. A high-temperature $\alpha + \beta$ anneal is substituted for the solution treatment under (*a*) for either of two reasons: (1) the retained β phase is unstable or in the β' condition; (2) the $\beta/\alpha + \beta$ transformation temperature is too high and causes undesirable grain-growth. The lower of the two isothermal temperatures affects particle size in the opposite direction and α grows irresolvably small with lower temperatures; this α has frequently an extremely embrittling effect.

(*d*) Quench-and-reheat type treatment. The weldment is heated to the same two temperatures as in (*a*) or (*c*), but is, between the two treatments, waterquenched. Since nucleation of α starts at lower temperatures on reheating than on step-quenching, the treatment results in larger particles and frequently, in better strength-ductility combinations.

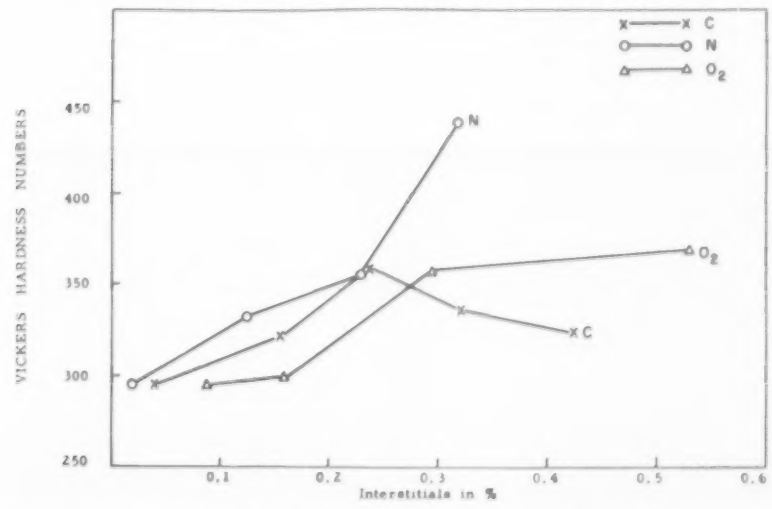


Fig. 4 Hardness variations in 5 Al–Ti double melted plate vs. interstitial

(3) Chemical Analysis

The alloy composition must be known with certainty for heat treatment based on phase relations to accomplish its ends. Nominal content is not satisfactory;[7] previous work on titanium weldability is tainted with uncertainty of true composition. Therefore, test results are presented in function of content according to chemical analysis as made from the finished sheet alloy. The unalloyed titanium sheet contained 0.04% C, 0.02% N_2 and 0.09% O_2 already present in the sponge; these plus the intentionally alloyed interstitials never add up to the amounts analyzed. Analysis tolerances are for aluminum $\pm$ 0.2 wt %, for nitrogen $\pm$ 0.01 wt %, for carbon $\pm$ 15% of the analyzed amount. H_2 and O_2 were determined by the vacuum fusion method at National Research Corp., Cambridge, Mass. No quick and inexpensive substitute has been found yet for the method of chemical analysis; hardness readings are only reliable within limits.

(4) Hardness vs. Purity

Hardness serves generally to indicate the quality of titanium sponge; the material used for this study measured 127 Bhn (equivalent to 147 Vhn) after tungsten-arc melting. Hardness readings are also applicable to alloys and were correlated to interstitial content

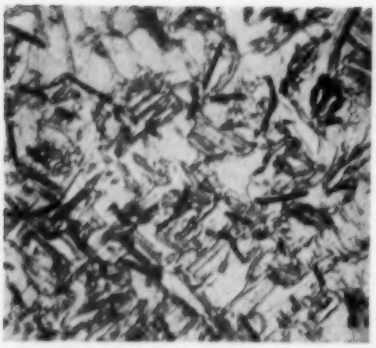


Fig. 6 Weld metal 5Al–0.24C–Ti, annealed at 1500° F. Poor way of polishing. UTS 129,800 psi; folding distance $5^1/_8$ in.; elongation 1%. X 750.

during preparation of the 5Al–Ti compositions. Figure 4 shows the interstitial effect on the hardness, 295 Vhn, of forged 5Al–Ti which serves as starting point of the three curves. Hardening by 0.24% C, 0.23% N_2 or 0.30% O_2, respectively, is nearly alike and attains 350 to 360 Vhn. Beyond that value the three curves diverge; carbide formation causes the carbon curve to fall off; oxygen continues to harden moderately, and the nitrogen effect grows stronger. With this information available hardness was cautiously used to check possible contamination during manufacture of the α alloy sheet.

(5) Hardness vs. Brittleness

Hardness traverses serve as a means of indicating weld embrittlement in steel welding metallurgy. Therefore, hardness traverses were run for all weldments tested and zone hardness was compared with ductility and location of failure. However, no general correlation was found to exist, high hardness does not indicate weld embrittlement and neither does it agree with high-strength values. Thus, hardness traverses in titanium weldments are of little help; even the formerly observed rule that weld zones with over 400 Vhn are brittle was found not to be always true.

(6) Testing Methods

The weld properties to be studied were strength and ductility. Strength was measured by the conventional tensile test performed with weld bead perpendicular to the stress. The gage length of the transverse weld tensile specimen is composed of zones with different properties and its measured ultimate strength depends upon the flow strength of the weld metal except for solution treated, structurally homogenized weldments. The test results demonstrate that the limitations of the method do not detract from its usefulness. A longitudinal tensile test with the weld bead in the stress direction had to be omitted because of scarcity of material.

The yield strength was not recorded because of the inhomogeneity of the gage length; the elongation was measured, although it is subject to the same restriction. Elongation results are not generally satisfactory; even when they show low ductility, the weldment frequently bends to a degree which makes it acceptable to aircraft manufacturers. Among the guided and free bend test methods with the weld bead in both the longitudinal and transverse directions, the transverse free bend test was found to best represent actual service and to be most explicit when the test samples were limited in quantity. The test was performed with a strip, 6 in. long, being compressed in a vise until cracks form or the sample snaps.* The weldment was termed ductile when it folded to a jaw spacing of 1 in. or less before failure. Bending takes place in the weakest zone, usually the weld metal; sometimes the brittle base metal away from the weld metal would shatter. Test results spread sufficiently to permit evaluation of bend ductility from a minimum of tests. The same test was also performed with the weld bead in the length axis. Since now all zones bent simultaneously, cracks originating in the most brittle zone propagate, because of the notch effect, and cause all zones to fail.

* An illustration is shown in Fig. 3.[1]

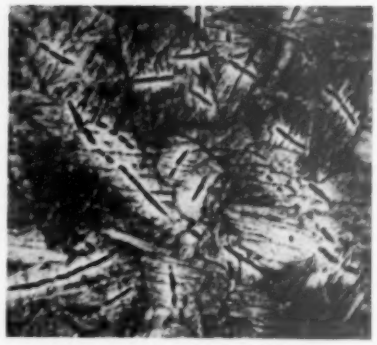


Fig. 7 Weld metal 5Al – 0.24C–Ti, annealed at 1500° F. Correct way of polishing. UTS 129,800 psi; folding distance $5^1/_8$ in.; elongation 1%. X 750

The guided bend test method forces the folding to occur in the weld metal; the test was performed with weld bead in both transverse and longitudinal direction. The bending jig shown in Fig. 5 has five interchangeable sets of wiping rolls and mandrels inserted in a biforked handle to which a protractor is attached; the mandrels have radii of 1, 2, 4, 6 and 8–T. The success of the method depends on choosing the proper mandrel and on the toughness of the test sheet. The 7Al–3Mo–Ti sheet, because of its strength, yields too small a spread of bending angles to permit pertinent information; also the test results scatter so that a large number of tests would have to be run from which an average result is to be computed. The method works better with the weak 25V–Ti alloy. Most of the time the four bend test methods give results consistent among them.

Metallographic specimens were conventionally prepared by mechanical polishing, since electrolytic polishing did not yield more relevant structures. Too heavy polishing however, distorts the surface layer which must be removed by etching; this fact invites overetching as shown in comparative Figs. 6 and 7. While titanium metal-

Fig. 8 Panorama of weldment 25V–Ti. The center of the weld is at right. X100. (Reduced by $^1/_4$ upon reproduction)

Fig. 9 Weld metal 8Al–Ti, annealed at 2050° F. X 750

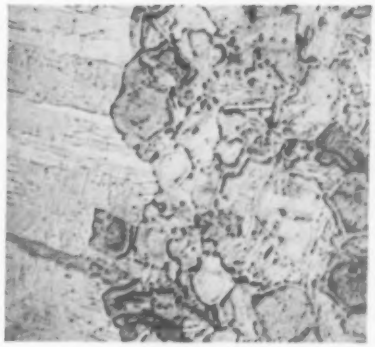


Fig. 10 Base metal 5Al–Ti, annealed at 1900° F. X 500

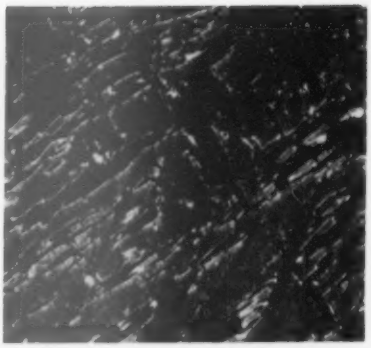


Fig. 11 Weld metal 5Al–Ti under polarized light (Heat 6299), annealed at 1900° F. X 250

lurgy has been concerned with equilibrium structures so far, the metallographer is confronted frequently with non-equilibrium structures in the weldments with and without interstitial additions. 20 c.c. HNO_3 + 20 c.c. HF + 60 c.c. glycerine was the etchant.

(7) Specimen Preparation

Selected DuPont A-1 sponge titanium from which approximately 10% of fines had been sifted contained, beside C, N_2 and O_2, 0.016% H_2 and 0.09% Fe. Aluminum of 99.99%+ purity was purchased from Aluminum Company of America. Calcium reduced vanadium came from Electro Metallurgical Company's pilot plant in Niagara Falls, N. Y. Molybdenum of 99.9%+ purity was supplied as sheet, 0.005 in thick, by Fansteel Metallurgical Corporation. Carbon in form of special graphite spectroscopic electrodes from National Carbon Company was crushed since powder is too fine to be arc melted for master alloy. Titanium nitride was prepared from sponge over which extra pure nitrogen (Linde Air Products Company) is passed at 1560° F. Oxygen master alloy was melted from sponge and high-purity titanium-dioxide (National Lead Company, South Amboy, N. J.).

Heats of the first melting operation ranged from 5 to 10 lb, heats of the second melting from 10 to 20 lb in weight; 500 lb were melted in all. Rods forged from the first ingots served for the consumable-electrode second melting. Second ingots were forged to slab and rolled to 1/16-in. sheet; the yield in sheet was 41% of the initial charge weight. Techniques of preparation and welding have been described.[1] Pains were taken to clean the material between operations and the techniques improved as the study developed. Forging temperatures were from 1950 to 2150° F., and rolling temperatures from 1600 to 1800° F.; the sheet, then, was cut into pieces, 3 x 6 in., welded, cleaned and slit with cut-off wheels into test pieces.

(8) Welding Technique

The inert-gas tungsten-electrode arc-welding setup with an oxy-acetylene cutting machine as travel part† has gradually become independent of the human factor. Electrodes of 1/16-in. diameter in direct polarity were used. Table 1 lists the welding variables for the different alloys. The heat input for 7Al–3Mo–Ti was on the high side; the breadth of weld metal and heat-affected zone increases even more in the V–Ti alloy (see Fig. 8) because of the low thermal conductivity in the β phase.

Since the alignment of the two pieces to be joined was time consuming they were superseded by a single test piece, 3 x 6 in., across which the arc was run effecting full penetration. Filler material as well as multiple passes were avoided because of the thin sheet gage (1/16 in.) used. A helium blanket under a hood attached to the welding torch protected the weld from the top and, through a slot in the copper back-up plates, from the underside.

† An illustration is shown in Fig. 2.[1]

Table 2—Mechanical Properties of 8Al–Ti

Heat No.	Condition*	Postheat treatment	Free bend test, transverse longitudinal: Folding distance, in.	Fail-ure†	Folding distance, in.	Guided bend test: Trans. diam, in.	Trans. angle	Long. diam, in.	Long. angle	Tensile test: Ultimate tensile strength, psi	Elongation % in 2 in.	Fail-ure†
6058	Pilot	As-rolled	4T/8	...	...	...	...	...	...	154,000	1.6	...
	Pilot	1600° F/30 min → WQ	1 3/16	...	...	3/4	11	...	...	95,500	12.5	...
	Pilot	1600° F/30 min → WQ	...	...	...	1	25	...	...	...	...	...
	Welded	1600° F/30 min → WQ	3T/16	HAZ	1 3/16	1	180	1	18	95,800	3.1	HAZ
	Pilot	1750° F/30 min → WQ	15/16	...	...	1/4	30	...	...	93,200	10.9	...
	Pilot	1750° F/30 min → WQ	...	...	...	1/2	21	...	...	...	...	...
	Pilot	1750° F/30 min → WQ	...	...	...	1	90	...	...	...	...	...
	Welded	1750° F/30 min → WQ	3 25/32	WM	1 7/8	1	180	1	30	89,200	3.1	WM
	Pilot	1900° F/30 min → WQ	7/8	...	...	1/2	25	...	...	99,300	12.5	...
	Pilot	1900° F/30 min → WQ	...	...	...	3/4	180	...	...	...	...	...
	Welded	1900° F/30 min → WQ	2 7/8	HAZ	1 3/4	3/4	180	3/4	15	92,100	4.7	HAZ
	Pilot	2050° F/30 min → WQ	17/32	...	...	1	180	...	...	95,600	3.1	...
	Pilot	2050° F/30 min → WQ	...	...	...	3/4	180	...	...	...	...	...
	Pilot	2050° F/30 min → WQ	...	...	...	1/2	61	...	...	...	...	...
	Welded	2050° F/30 min → WQ	4 3/16	HAZ	1 3/4	1/2	23	1	180	94,800	4.7	BM
84‡	Pilot	None	1/2	...	...	...	...	...	...	111,000	10.9	...
	Welded	None	13/32	BM	...	...	...	...	...	121,000	9.4	BM

* All specimens stress relieved 30 min. at 1500° F, except for the first test. † WM: Weld metal; HAZ: Heat-affected zone; BM. Base metal. ‡ Heat No. 84 prepared in a protected way.

Table 3—Hardness and Structure of Welded 8Al–Ti Sheet

Heat No.	Condition	Postheat treatment	Base metal Vhn	Base metal Structure	Weld metal Vhn	Weld metal Structure
6058	Welded	1600° F/30 min → WQ	326	Equiaxed α	341	Transformed β
	Welded	1750° F/30 min → WQ	314	Larger equiaxed α. Surface layer mostly α'	368	Serrated transformed β. Some "x" with fine α inside
	Welded	1900° F/30 min → WQ	345	Large equiaxed, transformed β	378	Large equiaxed α, center serrated, some α'
	Welded	2050° F/30 min → WQ	320	$\alpha + \alpha'$; surface layer of α'	354	$\alpha + \alpha'$; one surface α' other surface serrated α. See Figs. 4 and 5
	Pilot	2100° F/15 min → agitated WQ	...	Equiaxed transformed β. Some α' grains. Surface all α'	...	...
	Pilot	2150° F/10 min → agitated WQ	...	Same	...	...
84	Welded	None	275	Equiaxed α and some α'. Somewhat larger in HAZ	326	Cast structure of transformed β

II. Titanium-Aluminum System

The α field in the phase diagram of Fig. 1 extends to higher temperatures with increasing aluminum content; no β phase is retained on quenching. The two questions to be studied were: Can 8Al–Ti be made workable and weldable; and what effects have interstitial elements on 5Al–Ti?

(1) Weldments in 8% Al–Ti

When prepared from 147 Vhn sponge the alloy had been brittle and strong under any condition.[1] Pilot specimens of the purer 127 Vhn sponge alloy which also performed in a strong and brittle way (see Table 2) were heat treated in the β, $\alpha + \beta$ and α fields; the temperatures applied are marked in Fig. 1. Pilots lose brittleness and strength with increasing temperatures, but weldments remain brittle. After this first step, small pancake heats were melted which would require neither forging nor second melting operations. They were rolled at 1700 to 1800° F substantially below the 2000 to 2100° F required for forging, and were annealed between passes in a retort under slight helium pressure. The sheet No. 84 (Table 2) turned out to be very ductile in both the pilot and welded states. Hardness in the weld zones is below the 400 Vhn mark (see Table 3).

Therefore it is evident that the 8Al–Ti is workable and not inherently weld brittle. When prepared from selected sponge and protected from contamination, strength and weldability in 8Al–Ti has been achieved on a laboratory scale. The fact is of interest for alloy development work; it is suspected that past embrittlement was due to contamination which caused some still unknown phase transformation phenomenon, possibly related to hydrogen.

The microstructure, which had been described as all-α, actually is quench rate sensitive in the purer alloy (see Table 3 and Fig. 9) and shows two phases. The surface layer which has transformed instantaneously consists of light etching grains which do not stain in air; they are tentatively identified as α' phase which, having had no time for diffusion, transformed by martensitic shear.

Table 4—Nominal and Actual Compositions of 5Al–Ti Base Alloys

Test Nos.	Heat No.	Alloy (nominal), %	Composition (wt, %) Al	C	N_2	O_2	H_2	Fe
4020–4025	6299	5Al	5.19	(0.04)*	(0.02)	(0.09)	(0.016)	0.089
4588–4595	6741	5Al	4.70	0.034	0.021	0.087	0.016	0.095
4067–4072	6712	5Al–0.1C	4.83	0.094	0.023	(0.09)	(0.016)	(0.09)
4142–4149	6843	5Al–0.1C	4.95	0.154	(0.02)	(0.09)	(0.016)	(0.09)
4061–4066	6472	5Al–0.2C	5.19	0.219	(0.02)	(0.09)	(0.016)	(0.09)
4150–4157	6845	5Al–0.2C	5.15	0.236†	(0.02)	(0.09)	(0.016)	(0.09)
4073–4078	6729	5Al–0.3C	5.36	0.322	(0.02)	(0.09)	(0.016)	(0.09)
4107–4114	6729	5Al–0.3C	5.36	0.322	(0.02)	(0.09)	(0.016)	(0.09)
4158–4165	6731	5Al–0.4C	4.68	0.427†	(0.02)	(0.09)	(0.016)	(0.09)
4158A–4163A	6731	5Al–0.4C	4.68	0.427†	(0.02)	(0.09)	(0.016)	(0.09)
4043–4048	6336	5Al–0.1N	5.06	(0.04)	0.096	(0.09)	(0.016)	(0.09)
4085–4090	6713	5Al–0.1N	5.16	(0.04)	0.096	(0.09)	(0.016)	(0.09)
4037–4042	6335	5Al–0.2N	4.71†	(0.04)	0.231†	(0.09)	(0.016)	(0.09)
4049–4054	6335	5Al–0.2N	4.71†	(0.04)	0.231†	(0.09)	(0.016)	(0.09)
4178–4185	7723	5Al–0.3N	4.92	(0.04)	0.318	(0.09)	(0.016)	(0.09)
4079–4084	6366	5Al–0.1O_2	4.96	(0.04)	(0.02)	0.161	0.015	(0.09)
4099–4106	6366	5Al–0.1O_2	4.96	(0.04)	(0.02)	0.161	0.015	(0.09)
4116–4123	6707	5Al	4.94	(0.04)	(0.02)	0.247	0.016	(0.09)
4091–4098	6806	5Al–0.02O_2	5.40	(0.04)	(0.02)	0.294	0.013	(0.09)
4186–4193	7734	5Al–0.3O_2	5.07	(0.04)	0.030	0.531	0.038	(0.09)
4055–4060	6806	5Al–0.2C_2	5.40	(0.04)	(0.02)	0.294	0.013	(0.09)

* The contents listed in parentheses refer to interstitials present in the titanium sheet without any additions and constitute the average of a number of analyses.

† Average of two analyses.

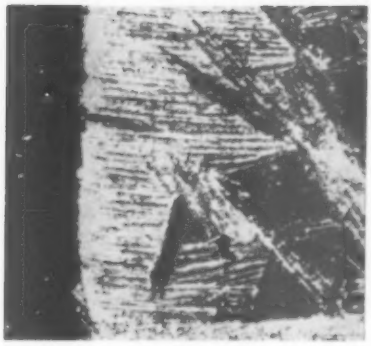


Fig. 12 Weld metal 5Al–Ti, under polarized light (Heat 6741), annealed at 1900° F. X 250

(2) Weldments in 5% Al–Ti

The questions to be studied in the 5% composition were: Whether and how much interstitials are required for embrittlement of pilot and weldment; whether weld-brittleness can be alleviated by post heat treatment, and whether and how embrittlement in any of the weld zones results from non-equilibrium microstructures.

The binary 5Al–Ti base alloy, four carbon alloys with 0.1, 0.2, 0.3 and 0.4% and three compositions each with 0.1, 0.2 and 0.3% nitrogen and oxygen were prepared; Table 4 lists both the nominal contents and sheet analyses. It will be noted that heat 6707, weighed without additions, contains 0.247% O_2 and that heat 7734 is high in interstitials; no explanation of the causes is advanced here.

(3) 5% Aluminum–Titanium without Additions

Two α configurations characteristic of thermal history exist: on quenching a serrated structure of transformed β forms along crystallographic planes; the width of the plates is the main variable. On isothermal annealing they become modified to equiaxed grains; this necessary annealing time can be short, as in the sheet core away from the surface where lower quench rates prevail. In Fig. 10, the transition between serrated surface layer and centerband of equiaxed grains is well defined.

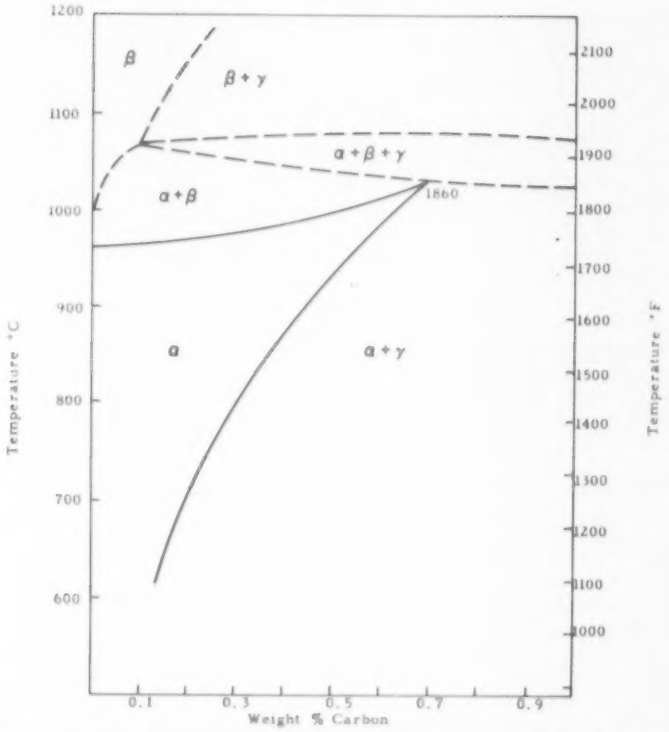


Fig. 13 Vertical section at 5% aluminum content of the partial Ti-Al-C system

Heat treatments were conducted for 30 min at 1900, 1700 and 1500° F; the temperatures are marked in the β and α fields of Fig. 1.

Specimens originating from heat 6299 have an averaged strength of 85,000 psi and those from heat 6741 of 120,000 psi (see Table 5). Ductility in transverse free bending is perfect under almost all conditions; specimens fold to well below the critical one-inch distance. The longitudinal weld also is ductile except for the 1700° F anneal; the transverse guided bend test shows that the weld

Table 5—Mechanical Properties of Nominal 5% Al–Ti Sheet

			Free bend test, Transverse		Free bend test, longitudinal		Guided bend test				Tensile test		
Heat No.	Condition*	Postheat treatment	Folding distance, in.	Failure†	Folding distance, in.	Failure†	Trans. diam, in.	Trans. angle	Long. diam, in.	Long. angle	Ultimate tensile strength, psi	Elongation % in 2 in.	Failure†
6299	Pilot	1500° F/30 min → WQ	13/32				1/4	43			84,100	15.6	
	Welded	1500° F/30 min → WQ	3/16	WM	1 1/8		3/8	180	1/4	53	86,600	15.6	BM
	Pilot	1700° F/30 min → WQ	7/16				1/8	45		38	86,500	12.5	
	Welded	1700° F/30 min → WQ	3/16	WM	1 13/32		1/2	180	1/4	50	80,500	10.9	BM
	Pilot	1900° F/30 min → WQ	2 13/16				1/8	45			86,600	15.6	
	Welded	1900° F/30 min → WQ	1/4	HAZ	5/16		1/2	180	1/4	69	91,300	10.9	BM
6741	Pilot	None	1/8				1/8	104			138,000	6.0	
	Welded	None	1/8	BM	13/16		1/8	90	1/8	78	115,000	7.0	HAZ/BM
	Pilot	1500° F/30 min → WQ	1/4				1/8	115			120,000	7.0	
	Welded	1500° F/30 min → WQ	1/8	BM	3/8		1/8	148	1/8	107	122,800	13.5	BM
	Pilot	1700° F/30 min → WQ									109,000	15.0	
	Welded	1700° F/30 min → WQ	1/8	BM	1/4		1/8	87	1/8	90	122,500	7.0	WM
	Pilot	1900° F/30 min → WQ									142,500	4.5	
	Welded	1900° F/30 min → WQ	1/8	BM	5/8		1/8	113	1/8	76	106,500	11.0	BM

* All specimens stress relieved 30 min at 1400° F after rolling.
† WM: Weld metal; HAZ: Heat-affected zone; BM: Base metal

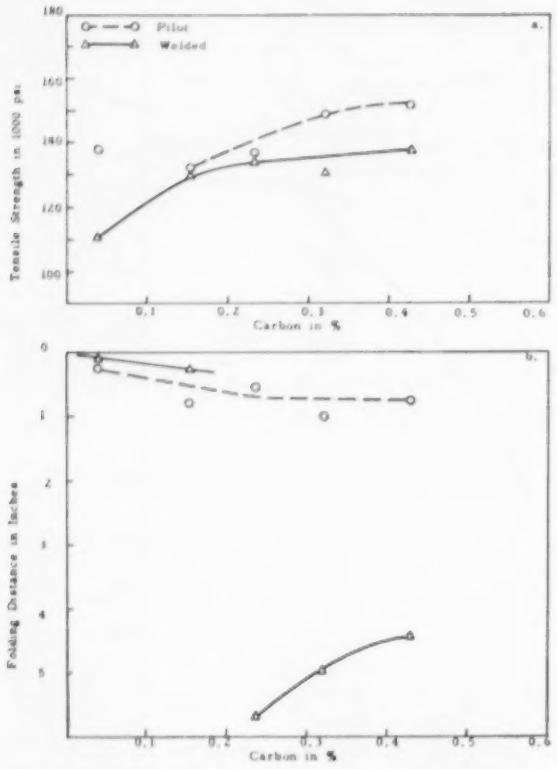


Fig. 14*a* and *b* Mechanical properties of weldments vs. C additions. 5Al–C–Ti sheet; as-welded

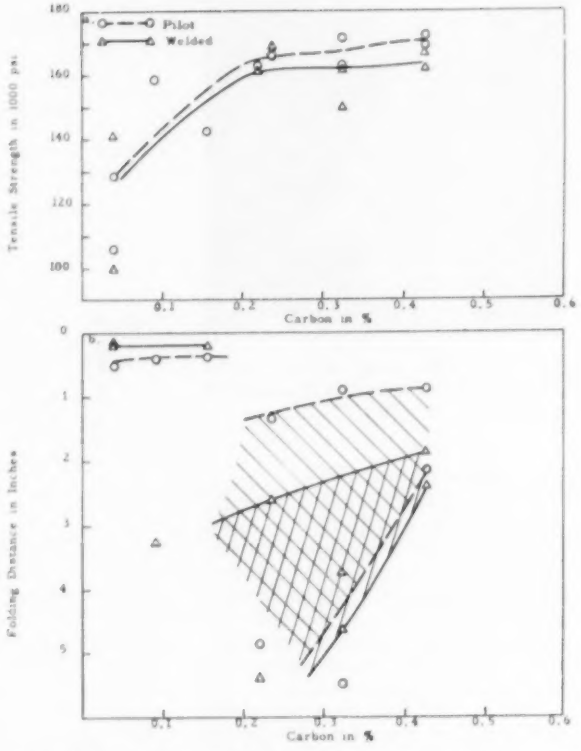


Fig. 16*a* and *b* Mechanical properties of weldments vs. C additions in 5Al–C–Ti sheet, 1700° F/30 min → WQ

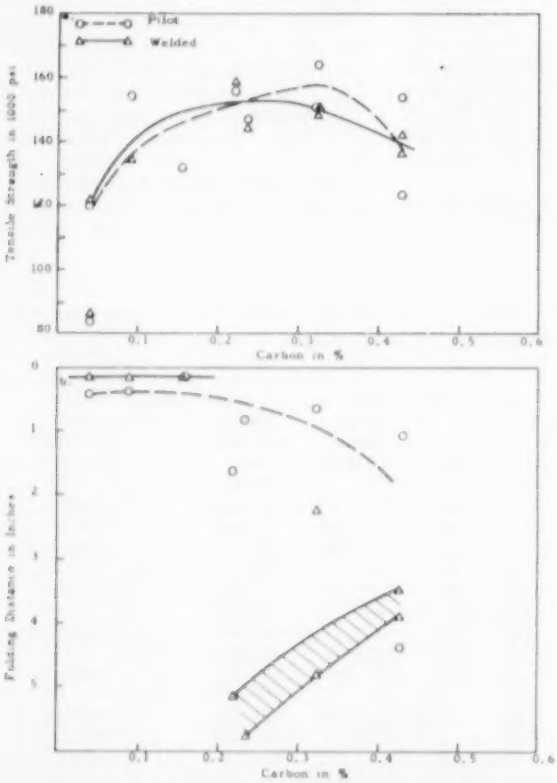


Fig. 15*a* and *b*. Mechanical properties of weldments vs. C additions. 5Al–C–Ti Sheet. 1500° F/30 min → WQ

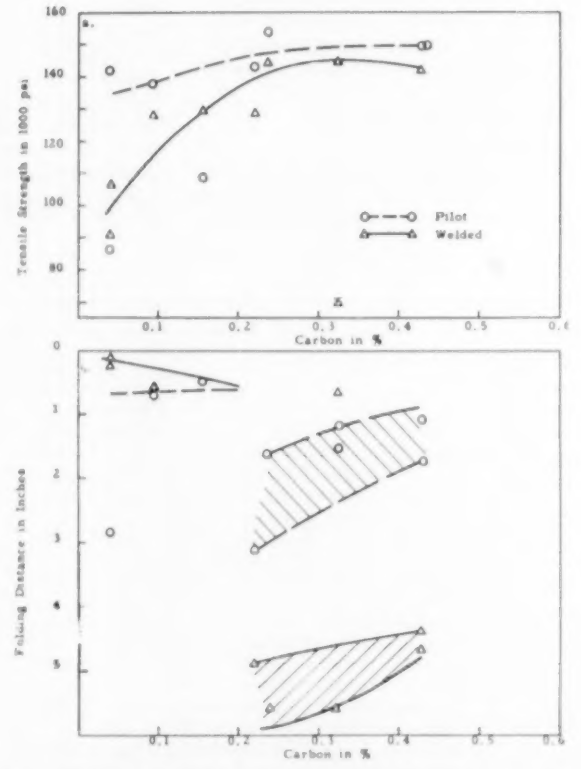


Fig. 17*a* and *b* Mechanical properties of weldments vs. C additions. 5Al–C–Ti sheet, 1900° F/30 min → W Q

metal is the ductile zone. Bend ductility of both heats are equally good, although the stronger set has a lesser elongation; its hardness trend after heat treatment is reversed. While the base metal of No. 6299 grows softer from 324 Vhn after 1500° F to 295 Vhn after 1900° F, the base metal of 6741 hardens from 288 to 323 Vhn, a trend encountered in the base metal of nitrogen bearing 5Al–Ti. Although the analyses of Table 4 furnish no clue, the structure of No. 6299 in Fig. 11 shows transformed β, while striations are visible under polarized light after the 1900° anneal in Fig. 12 (No. 6741). This slip plane precipitation and the reversed hardness trend point to nitrogen contamination as the possible cause of high strength in the latter heat.

(4) 5% Aluminum–Titanium with Carbon Addition

Carbon influences the structures intensely; while only β, $\alpha + \beta$ and α fields exist in the binary system of Fig. 1, the wedge shaped α field of Fig. 13[3] causes carbide precipitation on cooling of the ternary 5Al–C–Ti alloy as the α solubility recedes to as little as 0.1% at 1000° F. The high-temperature phases are more complex and several phase fields replace the β field around 1900° F. The weld metal and heat-affected zone are even more affected because, in them, carbide precipitates in a non-equilibrium configuration of intragranular plates and of particles in subgrain boundaries. The equilibrium carbide, on the other hand, as intergranular, pear shaped particles, is inoffensive except that it contributes to the known grain size effect.

Carbon is the least effective strengthener of the three interstitials, although its solubility in titanium is lowest, while as a rule, solutes with low solubility are the most potent ones. The properties of carbon bearing 5Al–Ti are listed in Table 4 and plotted in Figs. 14 to 17; they can be divided in groups of low (<0.15%), medium (<0.22%) and high (>0.22%) content. Low carbon affects pilot and weldment only moderately regardless of heat treatment. Medium carbon embrittles abruptly, while this effect does not grow worse in high-carbon alloy where pear shaped carbide forms and the wedge shaped α field permits re-solution of TiC in α during anneals.

Pilot and weld strengths are of the same magnitude; once the carbon solution is saturated, strength does not rise further (Figs. 14*a* to 17*a*). Maximum values of 160,000 psi are attained after 1500° anneal. While the pilot remains ductile through the whole range (dashed curve in Fig. 15*b*), the weldments stay ductile in low-carbon alloy only. Post treatments cause TiC precipitations and reduce moderately the strength. Evidently carbon strengthening does not coincide with brittleness; this is strictly an effect of non-equilibrium carbide as dramatically shown by the discontinuous curves of Figs. 14*b* to 17*b*.

Hardness traverses reflect the carbide influence as was to be expected from the C-curve of Fig. 4. Low carbon hardens to a range of 313 to 339 Vhn regardless of zone or heat treatment. Medium carbon alloy is hardest with 351 to 397 Vhn; it is significant that the base metal with 0.2% C is harder than the as-welded weld metal which, in welding, had reached the β + TiC phase field.

Both tensile and bend samples fail in the hard and brittle heat-affected zone (see Fig. 18) where non-equilibrium carbide forms in the subgrain boundaries. Sufficient TiC plates also form in high carbon weld metal to embrittle it (see Fig. 19); the α field at 0.3% C has grown too narrow for carbide precipitated in welding to dissolve on cooling. This carbide redissolves when post annealed in the "wedge" as shown by the structures of Figs. 7 and 20; non-equilibrium carbide is still present in the former while none is in the latter and, consequently, bend ductility is improved, although it contains twice as much carbon.

The high-temperature phase fields make themselves felt in the 1900° annealed 0.75% C weldment by presence of non-equilibrium carbide in Fig. 21. The 0.32% C pilot never affected by welding heat consists of equiaxed α and intergranular TiC (Fig. 22), and, therefore, is strong and ductile. Post anneals of longer duration than applied here possibly will modify the embrittling weld metal carbide into the inoffensive base metal carbide.

The high-carbon microstructure when quenched from the β + TiC field contains two phases as shown in Fig. 23.

(5) 5% Aluminum–Titanium with Nitrogen Addition

Nitrogen affects the binary 5Al–Ti system by raising the $\beta/\alpha + \beta$ boundary to 2300° F at 0.5% N and by broadening the $\alpha + \beta$ field.[5] The complete ternary system has not yet been determined; that makes it necessary to consider the Ti–N system for supplementary information. In it, the α field extends to 7% N beyond which composition a high-temperature $\alpha + \delta$ field exists; at approximately 1900° F a peritectoid reaction $\alpha + \delta \rightarrow \epsilon$ occurs;[4] the $\alpha + \epsilon$ field extends far toward the titanium end of the Ti–N system at lower temperatures. The boundary is not exactly known; it is suspected that it affects the microstructures observed in 5Al–N–Ti weldments.

The stress relieved alloy sheet has near the surface a structure of equiaxed α and of grains which do not stain in air and are not birefringent under polarized light; in this they resemble the α' phase in 8Al–Ti (lower right-hand corner in Fig. 24). The structure is quench-rate sensitive; the surface layer consists of equiaxed grains, in the sheet core a fine precipitate forms in amounts increasing with nitrogen (top right-hand corner in Fig. 24). The precipitate, which possibly is ϵ titanium nitride, extends, after 1500° anneal, into the heat-affected zone and in part of the weld metal.

The heat-affected zone on the left half of Fig. 24 forms a band adjacent to the base metal across the sheet; the band consists of α grains with an intense streak-shaped subgrain structure (see Fig. 25) which is caused by local plastic bending within the grains during the rolling deformation and is made visible by the diffusion of solute atoms at temperatures to which the heat-affected zone is subject.[7] The precipitate, if this assumption is correct, would consist of impurity atoms or of ϵ nitride.

Another phenomenon during low-temperature anneals is caused by deformation: a rolling texture develops in the base metal core after low-temperature anneal (see Fig. 26). Both, the dark etching band of the heat-affected zone and the rolling texture of the base metal vanish after protracted anneals (see Fig. 27) since the microstresses have subsided and the subgrain boundary precipitate has redissolved. The heat-affected zone now consists merely of grains intermediate in size between the grains of base metal and the coarse serrated weld metal (left hand side of Fig. 27).

Alloys containing over 0.2% N show striations originating from the former β grain boundaries in the weld metal (see also Fig. 12). The strain lines are caused by quench stresses and made visible either by the same kind of precipitation as in Fig. 25 or by lattice disturbances and the agglomeration of dislocations.[8]

Nitrogen is a potent strengthener; 0.3% N raises strength to 180,000 psi in the pilot and 160,000 psi in the weldment (Fig. 28*a*). Simultaneously, bend ductility deteriorates; both the pilot and weld ductility pass the one-inch mark at 0.18% N (Fig. 28*b*); the strength is 155,000 psi (pilot) and 145,000 psi (weldment) at that point.

The base metal hardens to 376 Vhn at 0.3% N content which means that the 1400° F stress relief has removed the work hardening evident in Fig. 4. The weld metal, which hardens to 390 Vhn at 0.3% N, is remarkably soft in 0.1% N alloy in which no striations are visible; it seems that the striation precipitate accounts for hardness and brittleness.

Heat treatments at 1500 and 1700° F reduce the pilot strength to 160,000 psi

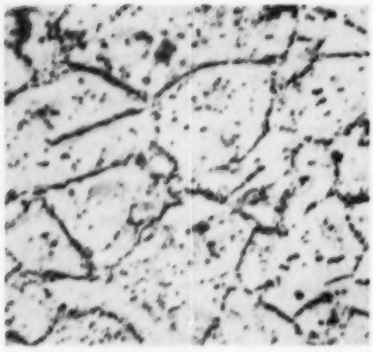


Fig. 18 Heat-affected zone 5Al – 0.24C–Ti. UTS 144,100 psi; folding distance $5^{11}/_{16}$ in.; elongation 1%. X 750

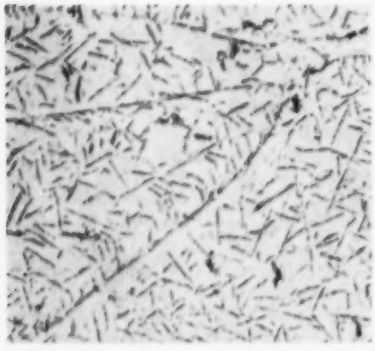


Fig. 19 Weld metal 5Al – 0.32C–Ti. UTS 131,500 psi; folding distance $4^{7}/_{8}$ in.; elongation 1.2%. X 150

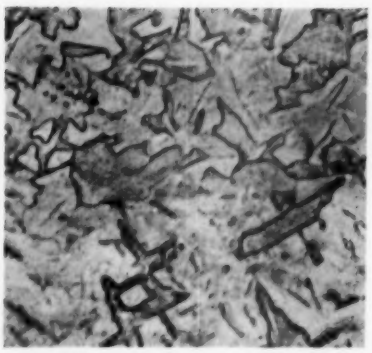


Fig. 20 Weld metal 5Al – 0.43C–Ti, annealed at 1700° F. UTS 142,500 psi; folding distance $1^{13}/_{16}$ in.; elongation 1.7%. X 500

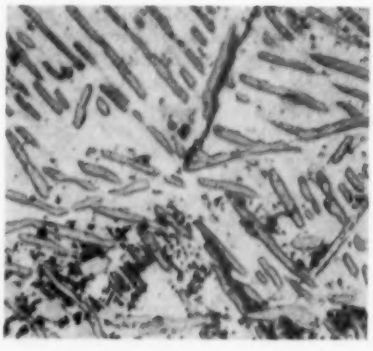


Fig. 21 Weld metal 5Al – 0.154C–Ti, annealed at 1900° F. UTS 130,000 psi; folding distance $^{7}/_{16}$ in.; elongation 7%. X 500

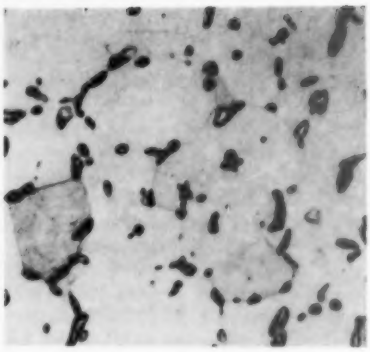


Fig. 22 Base metal 5Al – 0.32C–Ti, annealed at 1900° F. UTS 145,800 psi; folding distance $^{5}/_{8}$ in.; elongation 1.2%. X 250

Fig. 23 Base metal 5Al – 0.43C–Ti annealed at 2050° F. X 1000

Fig. 24 Heat-affected zone 5Al – 0.23N–Ti. X 150

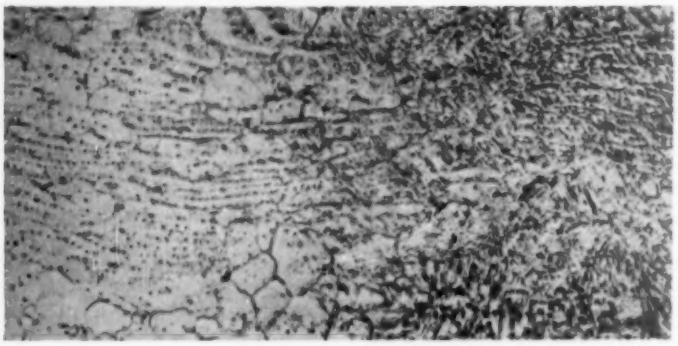


Fig. 25 Heat-affected zone 5Al – 0.23N–Ti. X 500

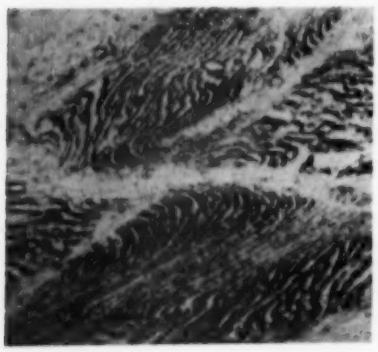


Fig. 26 Base metal 5Al – 0.23N–Ti, annealed 2 hr at 1300° F. X 150

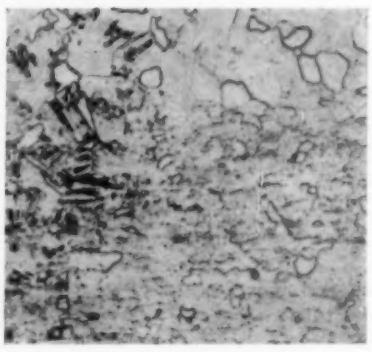


Fig. 27 Heat-affected zone 5Al – 0.23N–Ti, annealed 24 hr at 1300° F. X 150

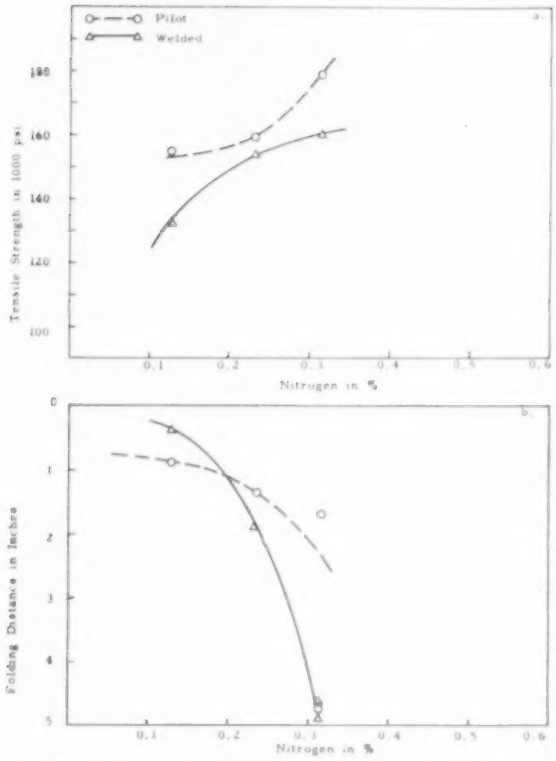


Fig. 28a and b Mechanical properties of weldments vs. N additions. 5Al – N–Ti sheet, as-welded

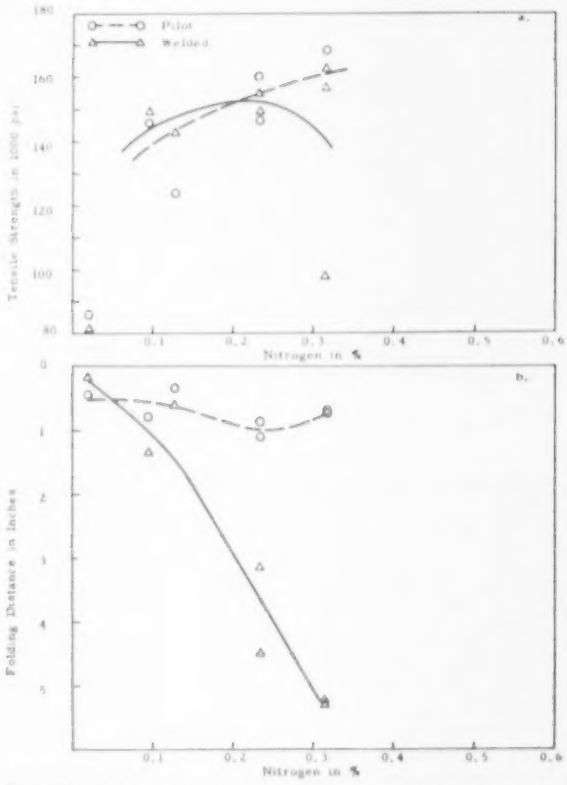


Fig. 30a and b Mechanical properties of weldments vs. N addition. 5Al–N–Ti sheet; 1700° F/30 min → WQ

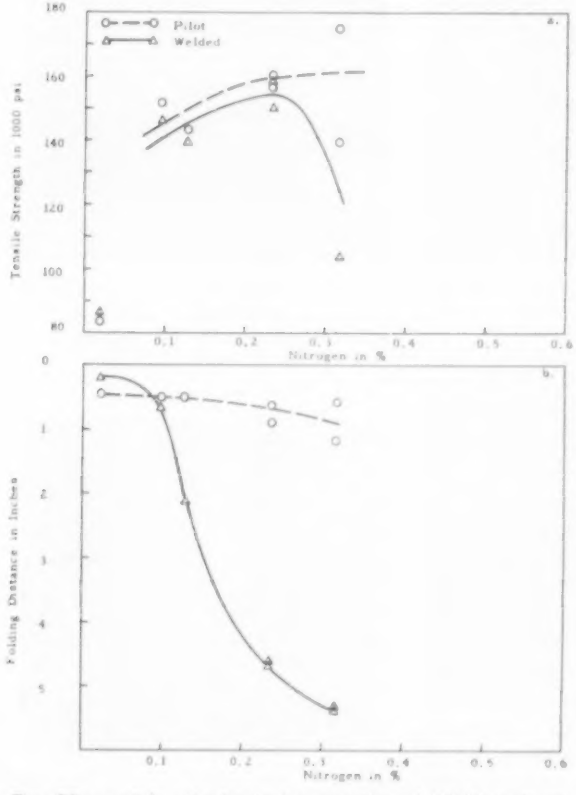


Fig. 29a and b Mechanical properties of Weldments vs. N addition. 5 Al–N–Ti sheet; 1500° F/30 min → WQ

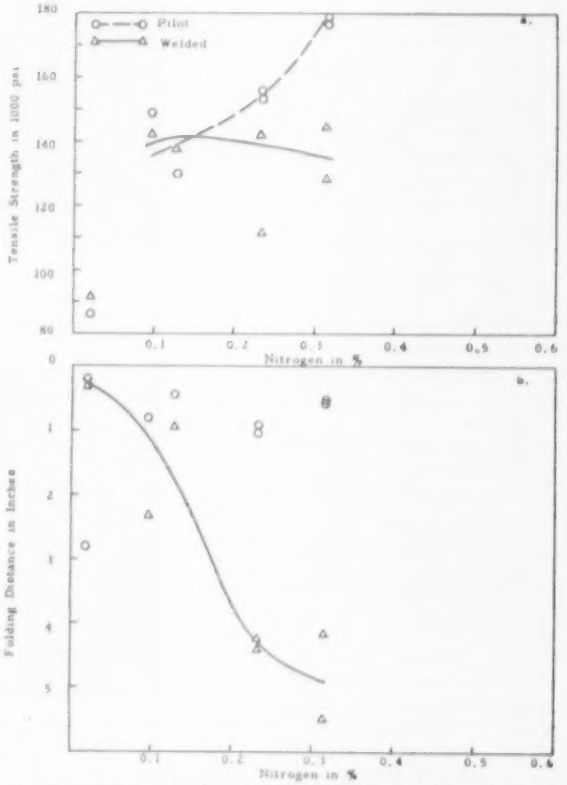


Fig. 31a and b Mechanical properties of weldments vs. N addition. 5Al–N–Ti sheet, 1900° F/30 min → WQ

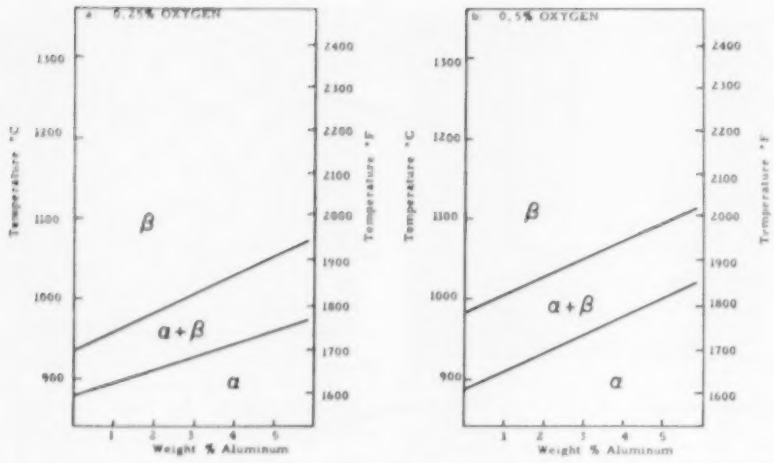


Fig. 32*a* and *b* Vertical sections at constant oxygen content of partial Al–O–Ti system

(Figs. 29*a* and 30*a*) while the 1900° anneal produces 180,000 psi. This reversal of trend with increasing temperature is possibly caused by the $\alpha + \partial \rightarrow \epsilon$ reaction. The welded strength is not substantially affected by 1500 and 1700° F anneals except for the brittle, high nitrogen sample. No such failure occurs after the 1900° treatment; the welded strength is low but stays on a constant level for all N-additions (see Fig. 31*a*).

All the annealed pilots regain ductility while weldments remain below the one-inch folding limit only to 0.1% N (Fig. 28*b* to 31*b*). Therefore, heat treatments as they were applied restore ductility to the medium and high N-pilot, but not to the weldment; no anneal repairs the damage caused by the strain line precipitate visible in the coarse weld metal.

Hardness traverses yield values of 319 to 375 Vhn in the base metal and of 350 to 400 Vhn in the weld metal.

(6) 5% Aluminum–Titanium with Oxygen Addition

Oxygen addition widens the $\alpha + \beta$ field of the 5Al–Ti alloy and, similarly to nitrogen, it shifts the $\beta/\alpha + \beta$ boundary to higher temperatures (see Fig. 32).[5] The full 5Al–O–Ti system is not yet known and the binary Ti–O diagram, which shows a vertical boundary between the TiO phase and the α phase, will possibly have to be corrected at lower temperatures, where the α + TiO field may well extend to the titanium end of the diagram as the $\alpha + \epsilon$ field of the TiN system.

The weld metal has the basket weave type of transformed β typical of oxygen bearing α titanium (see Fig. 33). Post heat treatment in the field does not alter the serrated weld metal structure, but high-oxygen weld metal structures show under polarized light narrowly spaced, discontinuous striations which grow parallel from the former β grain boundaries into the transformed β grains (see Fig. 34). This strain line precipitate embrittles the weld metal in a way similar to the nitrogen bearing weld metal.

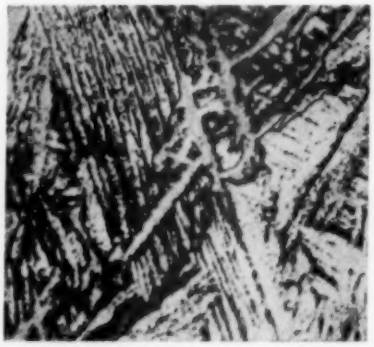


Fig. 33 Weld metal 5Al – 0.160$_2$–Ti, UTS 117,600 psi; complete closing (0 in.); elongation 10%. X 750

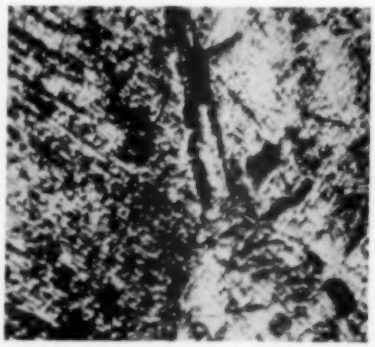


Fig. 34 Weld metal 5Al – 0.530$_2$–Ti, annealed at 1700° F under polarized light. UTS 116,300 and 158,200 psi; folding distance 5$^1/_8$ in.; elongation 3 to 4.5%. X 500

Another structural observation concerns martensitic α' needles which form in weld metal posttreated in the $\alpha + \beta$ field. The α' needles undergo a complex further transformation on cooling; their core as well as the adjacent matrix revert to β while the shell of the plate transforms to α (see Fig. 35). The base metal shows the same transformation mechanism (see Figs. 36 and 37) which is not confined to α titanium alloys, since 10% molybdenum-titanium[1] also shows α' needles which transform partly to α and partly to β (see Fig. 38).

Strength of 5Al–Ti containing 0.5% O_2 attains 180,000 psi (pilot) and 158,000 psi (weldment) (Fig. 39*a*). The difference in strength vanishes after 1500° anneals (Fig. 40*a*); higher temperatures weaken the weldment (Figs. 41*a* and 42*a*).

Oxygen affects the ductility of the pilot only after the $\alpha + \beta$ anneal. Weldability depends on oxygen content in the following way: low addition (<0.16%) does not alter the weldable, non-heat treatable character of 5Al–Ti. Medium alloy (<0.30%) produces ductile weldment except for 1900° post anneals. High alloy (<0.53%) renders

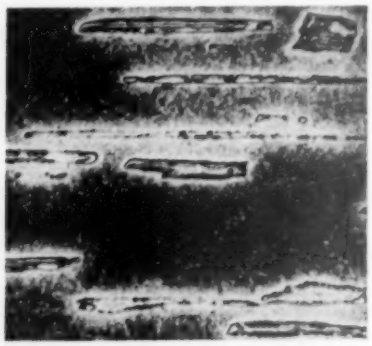


Fig. 35 Weld metal 5Al – 0.160$_2$–Ti, annealed at 1900° F. UTS 114,900 psi; folding distance $^{23}/_{32}$ in.; elongation 13%. X 1000

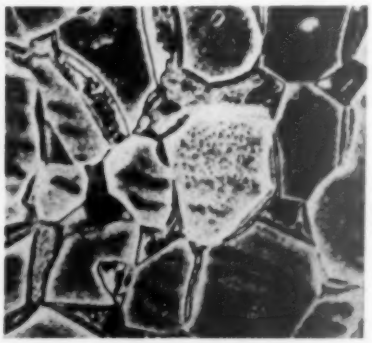


Fig. 36 Base metal 5Al – 0.160$_2$–Ti, annealed at 1900° F. (Same specimen as Fig. 35.) X 1000

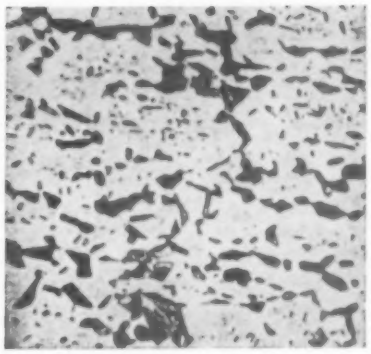


Fig. 37 Base metal 5Al – 0.290$_2$–Ti, annealed at 1900° F. UTS 139,000 psi; folding distance $^{15}/_{16}$ to $1^{1}/_{4}$ in.; elongation 5 to 6.3%. X 750

the sheet irreparably weldbrittle, and no postheat treatment applied succeeds in restoring weldability (Figs. 39*b* to 42*b*).

Hardness increases in the stress relieved sheet with oxygen content from 293 Vhn to 363 Vhn and in the weld metal from 313 Vhn to 403 Vhn. Heat treatments do not change the weld metal hardness and they soften the base metal slightly (280 to 350 Vhn); α anneals harden the high-oxygen base metal to 410 Vhn; it remains bend ductile, the high 400 Vhn level notwithstanding.

(7) Conclusion and Summary: Weldments in Ti–Al Sheet

The weldability of Ti–Al is summed up in the following as a function of interstitial content, of annealing temperatures and of aluminum composition.

(*a*) *Weldability vs. Interstitial Content.* 5Al–Ti has been alloyed with from 0.1 to 0.4% (nominal) carbon, nitrogen and oxygen. The mechanical properties in pilot and welded conditions have been tested, compared with the 5Al–Ti base alloy, and have been correlated to the microstructure of the weld zones.

The test methods were: tensile test with the weld in transverse direction, free and guided bend tests with weld in transverse and longitudinal direction, and hardness traverses. Under the conditions of this study, the transverse free bend ductility and tensile strength are the most revealing methods. Hardness measurements are useful for control of contamination during melting and forging. Results were evaluated on the basis of chemical analysis of the finished sheet.

The base alloy structure is quench rate sensitive showing equiaxed α in the center of sheet and transformed β at the surface. Two heats yielded strength values of 85,000 psi and 120,000 psi. The alloy is non-heattreatable, i.e., ductile in pilot and welded condition.

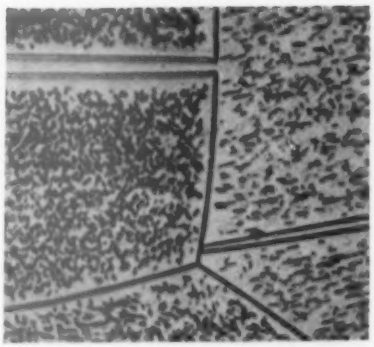


Fig. 38 Weld metal 10Mo–Ti, annealed 15 min at 1650° and 60 min at 1380° F. X 1000

The ternary 5Al–C–Ti system has an α field extending to 0.7 C at 1800° and to 0.1 C at 1000° C. This feature dominates the structures according to thermal history of the different weld zones. Sheet with less than 0.2 C does not contain carbide, has strength of 150,000 psi (pilot) and 138,000 psi (welded) and is ductile. Over 0.2 C causes nonequilibrium, embrittling carbide to precipitate in the weld metal and heat-affected zone. The pilot, where intergranular carbide forms, retains ductility to higher C content.

Nitrogen addition widens the α and

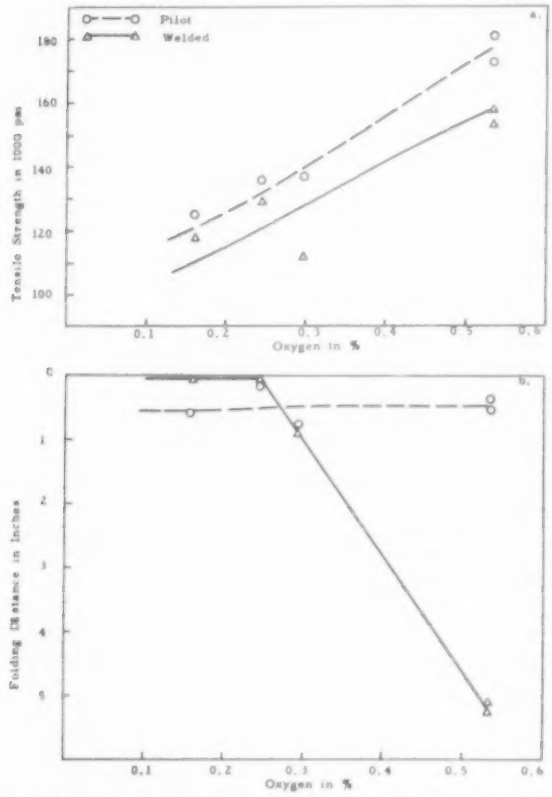


Fig. 39*a* and *b* Mechanical properties of weldments vs. O_2 additions. 5Al–O_2–Ti sheet; as-welded

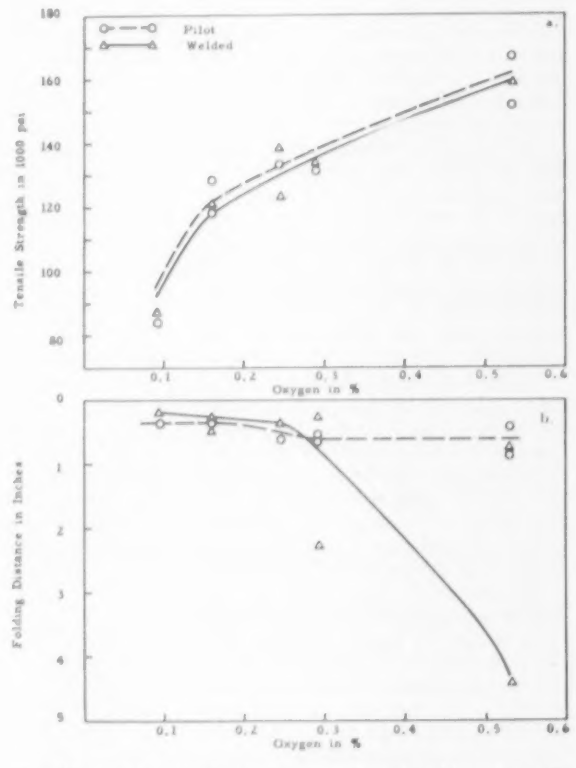


Fig. 40*a* and *b* Mechanical properties of weldments vs. O_2 additions. 5Al–O_2–Ti sheet; 1500° F/30 min. → WQ

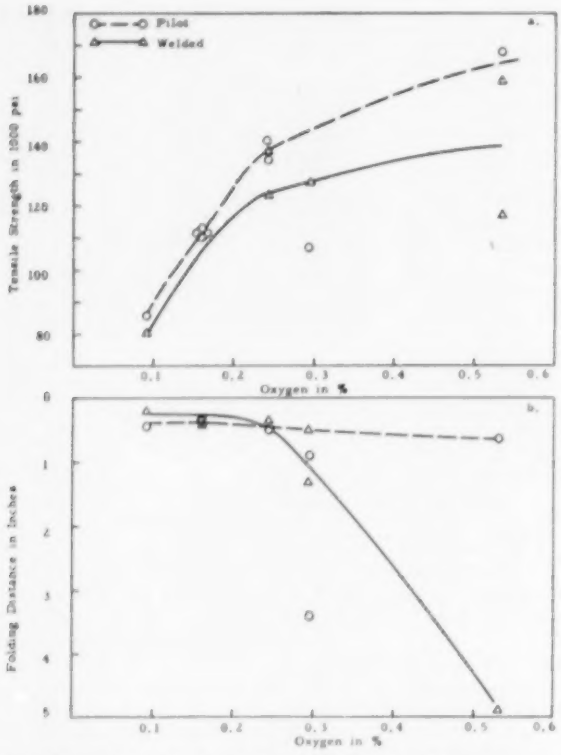


Fig. 41*a* and *b* Mechanical properties of weldments vs. O_2 additions. 5Al–O_2–Ti sheet; 1700° F/30 min → WQ

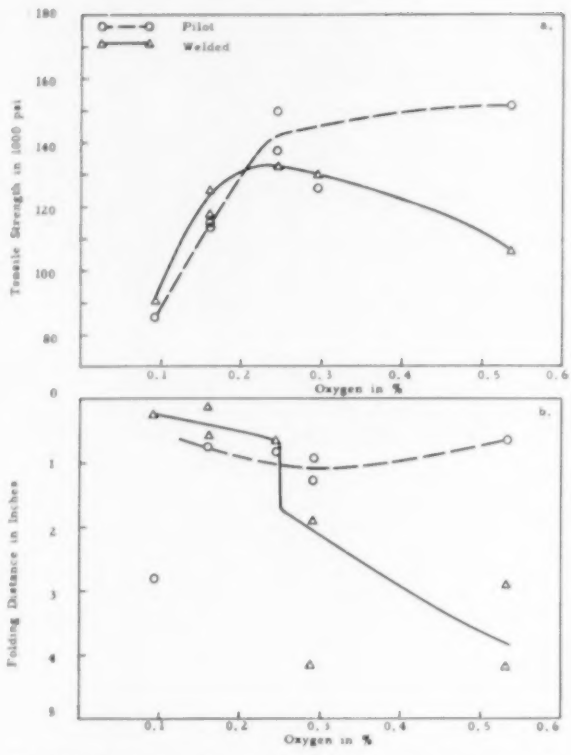


Fig. 42*a* and *b* Mechanical properties of weldments vs. O_2 additions. 5Al–O_2–Ti sheet; 1900° F/30 min → WQ

$\alpha + \beta$ fields; in the Ti–N diagram, the $\alpha + \epsilon$ phase field extends far to the titanium end. A precipitate, possibly related to the presence of dislocations, develops in the base metal after deformation and in the heat-affected zone, grows more intense at 1300° F and eventually redissolves when stresses have been relieved. Nitrogen is a potent strengthener; the pilot strength increases to 180,000 psi. But N embrittles more than either C or O. Weldments remain ductile, i.e., within the critical one-inch limit of the transverse free bend test, to almost 0.2% N and attain 145,000 psi; pilots embrittle at the same N content.

Oxygen also widens the α and $\alpha + \beta$ fields and shifts the $\beta/\alpha + \beta$ boundary to higher temperatures; this effect tends to make the β solution treatment impracticable. The Ti–O diagram has an α + TiO phase field which possibly extends far to the left at lower temperatures as does the $\alpha + \epsilon$ nitride phase. Oxygen strengthens the pilot and welded sheet substantially to 180,000 psi and 158,000 psi for 0.5% O_2. Ductility of the pilot is not greatly affected, but weld ductility is satisfactory only to 0.25%, then starts deteriorating. To 0.16% O_2 does not alter the characteristics of the non-heattreatable 5Al–Ti.

(*b*) The non-heattreatable quality of 5Al–Ti is altered by interstitial additions in the following way:

At 1700° the wedge shaped α field extends so far that all C-compositions are in the α field and carbide redissolves. Longer heat treatments may improve combined strength-ductility values. Post annealed weldments attain 160,000 psi; they grow no stronger nor more ductile than the as-welded sheet.

Striations in the coarse grained weld metal containing N are caused by quenching stresses and made visible by strain line precipitate which possibly is the ϵ nitride and appears after the 1700° anneal. The pilot strength is reduced to 160,000 psi after 1500° and 1700° F treatment, but equals the original strength of 180,000 psi after the 1900° anneal. Weldments with over 0.23% N fail by premature, brittle fracture. No postheat treatment succeeded in restoring ductility to weldments, while high N pilots had markedly improved bend ductility after annealing.

Striations exist also in the post treated weld metal with oxygen content. Globular precipitation occurs inside light etching grains tentatively identified as α'. Martensitic α' needles exist in the heat-treated weld metal; they transform partly to α while their interior and the adjacent matrix revert to β. Weld microstructures pass through complex transformation mechanisms involving non-equilibrium phases before equilibrium α eventually forms. Pilot and weld strength is 160,000 psi after 1500° anneal and falls off after higher temperature treatment. Postheat treatments in the $\alpha + \beta$ and α fields do not restore weldability when it had been lost in the as-welded high O_2 compositions.

(*c*) 8Al–Ti previously considered not workable has been made weldable. When quenched from the β field the alloy has a two phase structure of α and α'.

(*d*) Some optimum combinations of strength and ductility in Ti–Al weldments are listed below:

Ultimate tensile strength, psi	*Folding distance, in.*	*Alloy composition, wt. %*	*Postheat treatment*
121,000	15/32	8Al–Ti	As-welded
131,000	5/16	5Al–0.15 C–Ti	As-welded
147,000	11/16	5Al–0.10 N_2–Ti	1500° F, 30 min
132,000	9/8	5Al–0.25 O_2–Ti	1500° F, 30 min

References

1. Meyer, H. M., and Rostoker, W., "Effects of Alloying Elements on the Weldability of Titanium Sheet," THE WELDING JOURNAL, 33 (4), Research Suppl. 173-s (1954).
2. Meyer, H. M., "Weldments in the Titanium-Manganese Sheet Alloy RC-130A," *Ibid.* 33 (8), Research Suppl., 417-s to 421-s (1954).
3. Hansen, M., McPherson, D. J., and Rostoker, W., "Constitution of Titanium Alloy Systems," Technical Report 53-41 on Contract AF 33(038)-16347 RDO, No. 463-6-6SR-1 (February 1953).
4. Lillie, C. R., and Kessler, H. D., "Improving Titanium-Aluminum Binary Alloys by the Addition of a Third Component," Reports on Contract No. DA 11-022-ORD-244.
5. Kessler, H. D., Rostoker, W., Van Thyne, R. J., "Titanium Phase Diagrams," Technical Report 52-335 on Contract AF 33(038)-8708 (Nov. 1953).
6. Cadoff, I., Palty, A. E., "Binary Alloys of Titanium with Carbon, Nitrogen, Oxygen and Boron," Final Report on Contract No. DA 30-069-ORD-76 (October 31, 1952).
7. Cahn, R. W., "Slip and Polygonization in Aluminum," *Jnl. Inst. Met.*, **79**, 129 (1951).
8. Jacquet, P. A., "Recherches Expérimentales sur la Microstructure de la Solution Solide Cuivre-Zinc 65/35 Polycristalline Très Faiblement Déformée par Traction et sur son Évolution au Recuit entre 200 et 600°C," *Acta Metallurgica*, **2**, 752 (Nov. 1954).

UNIFORM NOTATION SYSTEM FOR PRESSURE-VESSEL SHELL THEORY

A standardized nomenclature for shell design prepared by a subcommittee of the Pressure Vessel Research Committee, Welding Research Council

ABSTRACT. This is a final revision incorporating the comments and suggestions of leading authorities in the fields of shell design and structural mechanics. The intent of this paper is to simplify the reading of shell theory literature and to facilitate communication among investigators in these fields. Definitions of terms and standard symbols are given for shells of revolution in general and also for the right circular cylinder. It is felt that necessary modifications of this notation for special shapes and types of loading can best be given in a specific context.

Introduction

IN AN effort to establish a standard notation system for pressure-vessel shell theory, the Design Division of the Pressure Vessel Research Committee, in 1953, established a subcommittee to study and report on this problem. The following notation is the result of two years of study by this subcommittee, which was given valuable aid from contributions by PVRC members and other interested parties.

The intent of the subcommittee was to standardize pressure-vessel shell nomenclature in order to make it easier to read material on shell theory and to facilitate communication between independent investigators.

In the study, an effort was made to utilize, in so far as was possible, nomenclature which has been in common usage and with which most engineers are currently familiar. It was found impossible, however, to utilize completely any existing notation system since no such system appeared to have sufficient scope.

It is recognized that some individuals will disagree with this system in certain particulars but it is the feeling of the committee that the system represents a reasonable compromise between the demands of theoretical and practical extremes.

In certain instances, it may be necessary to modify this notation to cover special shapes. For example, certain definitions and sign conventions, which may need further explanation in the case of a torus, can better be given in a specific context.

It will be noted that symbols have been included in the notation for a right circular cylinder for certain quantities associated with special types of loading which have not been included in the general shell notation. This has arisen from wider interest in the effects of special loads on cylindrical shells. Furthermore, it should be understood clearly that, in the interest of clarity and brevity, no attempt has been made to provide for all possible types of loading for either the general shell or the right circular cylinder.

General Definitions

Shell of Revolution. Surface generated by the revolution of a curve about an axis. (In particular cases it is convenient to substitute "head" or "cylinder" for "shell.")

Given a shell of revolution and a point on its unstrained middle surface, define planes as follows:

Meridional Plane. The plane passing through the axis of the shell and the point.

Latitudinal Plane. The plane perpendicular to the axis of the shell and passing through the point.

Tangent Plane. The plane tangent to the midsurface of the shell at the point.

Normal Plane. The plane perpendicular to both the meridional and tangent planes and passing through the point.

With this point, the following quantities are associated (see Fig. 1):

R_N—normal mean radius, radius of curvature of middle surface of shell section in normal plane, inches
R_M—meridional mean radius of curvature of middle surface of shell section in meridional plane, inches
R_L—latitudinal mean radius, radius of curvature of middle surface of shell section in latitudinal plane, inches
r—radial co-ordinate, inches

Subcommittee on Uniform Notation, Design Division, PVRC: D. K. Davies, *Chairman*, R. L. Graves and C. E. Taylor.

Reprinted from June 1955 issue of *Mechanical Engineering*, pp. 505-507.

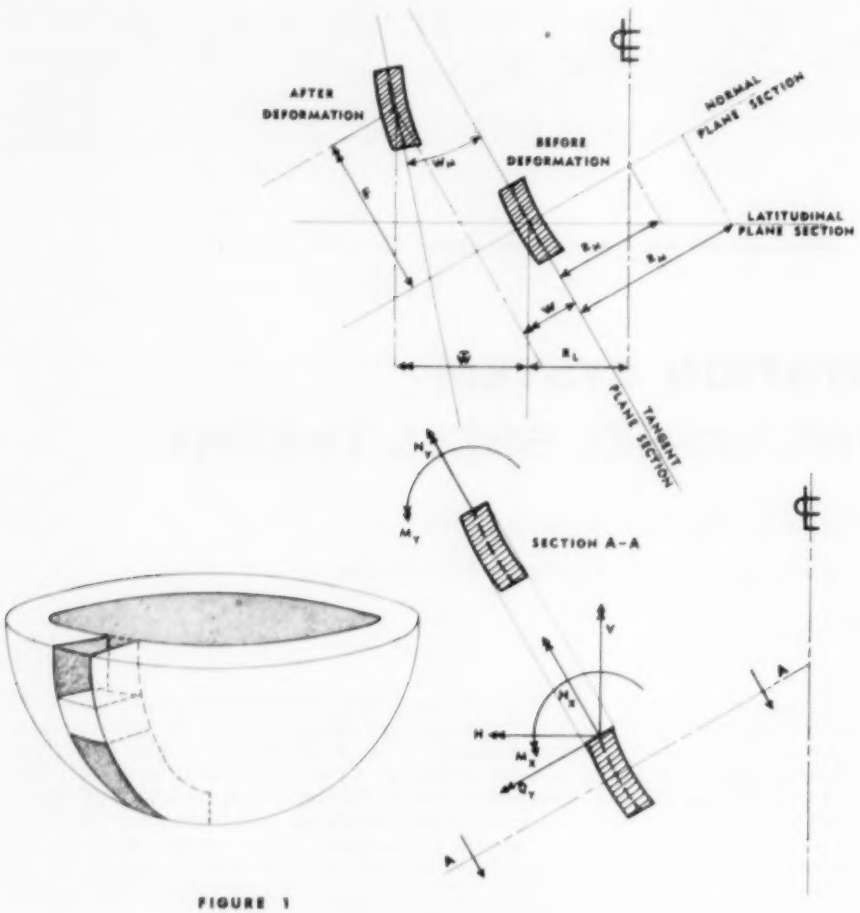


FIGURE 1

NOTE: ⟷ DENOTES POSITIVE DIRECTION

x—variable distance along middle surface of shell in meridional plane measured from some reference point, inches

y—variable distance along middle surface of shell in latitudinal plane measured from some reference point, inches

ϕ—angle between normal to shell middle surface and shell axis in meridional plane, radians

θ—angle in latitudinal plane between meridional plane and reference meridional plane, radians

z—variable distance from middle surface of shell normal to middle surface (positive away from shell axis), inches

u—longitudinal displacement, displacement (component) in intersection of meridional and tangent planes, inches, in direction of x

v—circumferential displacement, displacement (component) in intersection of latitudinal (or normal) and tangent planes, inches, in direction of y (positive when it increases distance of point from a reference meridional plane)

w—radial displacement, displacement (component) in intersection of meridional and normal planes, inches, in direction of z

$\bar{w}$—displacement normal to axis, displacement (component) in intersection of meridional and latitudinal planes, inches
(Note: displacement components are positive when they increase the distance of the point from the shell axis)

K—change in curvature (use subscript N, M, or L to denote specific item), positive when it tends to put outside of shell in compression, inches

W—rotation, change of angle of tangent line to middle surface (use subscript N, M, or L, etc.) (sign convention to be established for particular case)

ϵ_x—axial strain, strain in direction of x, inches per inch

ϵ_y—circumferentialstrain, strain in direction of y, inches per inch

ϵ_z—radial strain, strain in direction of z, inches per inch

N_x—axial force in direction of x, pounds per inch

N_y—circumferential force in direction of y, pounds per inch

N_z—force, in direction of R_M, pounds per inch

H—force resultant normal to axis, in meridional plane, pounds per inch

V—force resultant parallel to shell axis, pounds per inch

Q_y—radial shear, shear in direction of R_M on section in direction of y, pounds per inch

M_x—axial moment, moment on element in direction of y and acting in meridional plane, inch-pounds per inch

M_y—circumferential moment, moment on element in direction of x and acting in normal plane, inch-pounds per inch.
(Note: Moments which tend to put the outer surface of the shell in compression are positive.)

t—thickness of head or shell, inches (may be variable)

E—modulus of elasticity, psi

ν—Poisson's ratio

G—shear modulus equals $E/2\ (1 + \nu)$, psi

D—$Et^3/12(1 - \nu^2)$, inch-pounds

$$\lambda^4 = \frac{3(1 - \nu^2)R_M^4}{R_N^2 t^2}$$

p—pressure acting on middle surface of shell, normal to middle surface (positive when acting away from shell axis), psi. It is necessary to modify this definition for thick-shell theory

dot or prime—derivative with respect to independent variable

d—diameter of opening in shell, inches

For the thin, right circular cylindrical shell illustrated in Fig. 2 the following nomenclature is used:

R—mean radius of cylindrical shell, inches

L—length of cylindrical shell, inches

t—shell thickness, inches

x—axial co-ordinate, inches

y—circumferential co-ordinate, inches

z—variable distance from middle surface of cylinder normal to middle surface (positive away from cylinder axis)

r—radial co-ordinate (positive outward), inches

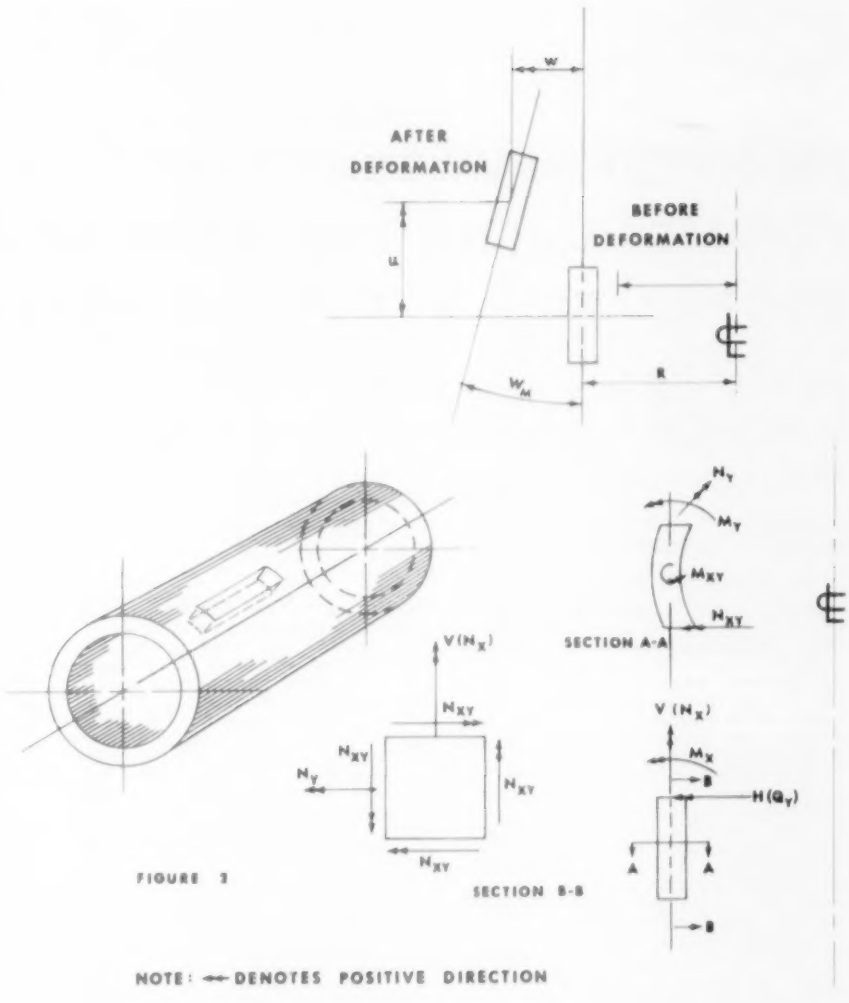


FIGURE 2

θ—angle in latitudinal (normal) plane between normal to cylinder middle surface and a reference normal, radians

u—longitudinal displacement, component, inches

v—circumferential displacement, component, inches

w—radial displacement, component (positive away from axis), inches

ϵ_x—normal strain in axial direction (+ denotes tension), inches per inch

ϵ_y—normal strain in circumferential direction, inches per inch

ϵ_z—normal strain in radial direction, inches per inch

γ_{xy}—shear strain in middle surface, inches per inch

W_y—rotation, change of angle of tangent to shell in latitudinal plane, radians (sign convention to be established for particular case)

K—change in curvature (positive when it tends to put outside of cylinder in compression)

W_{xy}—twist of middle surface, radians

N_x or V—normal force per unit length in axial direction (positive when tension), pounds per inch

N_y—normal force per unit length in circumferential direction, pounds per inch

N_{xy}—shear force per unit length on elements cut by generators, pounds per inch

M_x—axial bending moment per unit of circumference, inch-pounds per inch

M_y—circumferential bending moment per unit length, inch-pounds per inch

Q_x—radial shear on section in direction of x, pounds per inch

Q_y or H—radial shear on section in direction of y, pounds per inch

M_{xy}—twisting moment per unit length on element cut out by generators, inch-pounds per inch

σ_x—normal stress in axial direction (+ denotes tension), psi

σ_y—normal stress in circumferential direction, psi

τ_{xy}—shear stress on element cut out by generators, psi

p—intensity of uniform pressure acting normal to surface of cylinder at middle surface, psi

E—modulus of elasticity, psi

ν—Poisson's ratio

G—shear modulus equals $E/2\ (1 + \nu)$, psi

$D = Et^3/12\ (1 - \nu^2)$, inch-pounds

$$\beta^4 = \frac{3\ (1 - \nu^2)}{R^2 t^2}$$

MODIFIED NAVY TEAR TEST FOR MEASURING THE WORK OF FRACTURE PROPAGATION IN DUCTILE METALS

Description of test and application to the study of fracture properties in mild steel plate, 1/4 in. thick

BY HUGH E. ROMINE

SUMMARY. The original Kahn design of Navy tear test was modified by using Schnadt's roller bearing principle to eliminate unwanted plastic deformation. The modified design was found suitable for an approximate determination of Irwin's dW/dA value (rate of change of fracture work with fracture area) in the ductile fracture of a mild steel plate, 1/4 in. thick. The load-strain values were obtained with an *X-Y* recorder and SR-4 strain gage measuring circuits.

Substantial differences in dW/dA were found between longitudinal and transverse tear tests, regardless of heat treatment. The lower dW/dA occurred in the transverse tests and was thought to be caused by the stress-raising effect of the sharp ends of inclusions elongated by rolling. Transverse dW/dA was improved by normalizing. Additional annealing resulted in a further increase but the most favorable combination of dW/dA and yield point was found in normalized-only plate. The general value of heat treatment would, of course, depend upon the original condition of the plate being tested. The mean value of dW/dA in all the transverse tests of the plate as received was 3700 in.-lb/in.^{2}, at room temperature and with a slow strain rate. The lowest test value was about 3000 in.-lb/in.^{2}. The level of transverse dW/dA apparently was lowered by a high inclusion content and raised by normalizing. Other possible factors in dW/dA level, not clearly evaluated, may include grain size, microstructure, metal flow properties and residual stresses.

Hugh E. Romine is head, Metallurgy Division, Terminal Ballistics Department, U. S. Naval Proving Ground, Dahlgren, Va.

The opinions or assertions contained herein are the private ones of the writer and are not to be construed as official or reflecting the views of the Navy Department or the naval service at large.

Introduction

Good resistance to a tearing type of fracture is desirable in some applications of metals. G. R. Irwin suggested the use of incremental fracture work divided by the corresponding incremental fracture area, dW/dA, for measuring tear strength.[1] The standard Navy tear test developed by N. A. Kahn and E. A. Imbembo has been used for rating ship plate by measuring the energy to cause fracture.[2] This test appeared suitable for average dW/dA determination if modified to confine plastic working to the tensile zone of fracture. Actually total W and A were measured for the continued propagation of previously started cracks. There was ample evidence to show that in these tests dW/dA was constant and therefore W/A was essentially equivalent to dW/dA.

The dW/dA value is considered to be of fundamental importance in fracture phenomena and useful for evaluating the effects of strain rate, temperature and some other conditions of interest. Although dW/dA is not necessarily a materials constant, it is a measure of the fracture strength of a structure or testpiece in the presence of a crack.

Material

A mild steel plate, 1/4 in. thick, was chosen for the initial testing because this steel is easy to machine and because much published data were available. The material was tested in the as-received or mill condition except for one comparison which included labo-

Table 1—Chemical and Physical Properties of Mild Steel Plate Used in Tests

Chemical analysis, %

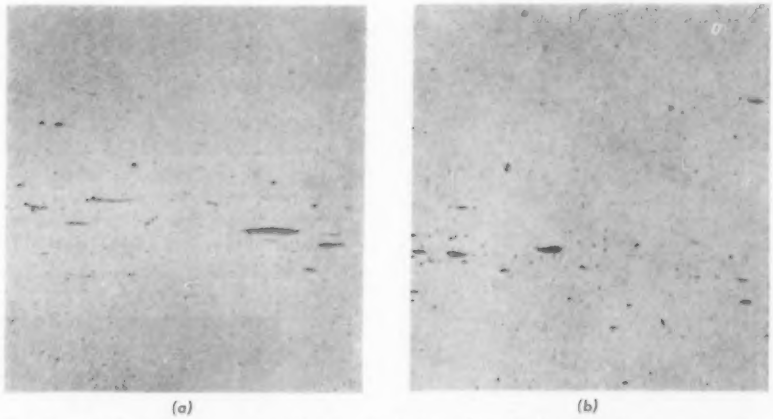
C	*Mn*	*P*	*S*	*Si*	*Ni*	*Cr*	*Mo*	*Cu*	*Al**
0.19	0.43	0.015	0.033	0.02	0.14	0.07	0.02	0.25	Less than 0.01

Tensile properties and hardness (standard flat tensile specimens)

Condition	*Direction*	*Upper yield point, psi*	*Lower yield point, psi*	*Tensile strength, psi*	*Elongation, %*	*Reduction of area, %*	*Brinell† hardness, 1500 kg*
As-received	Longitudinal	43,200	41,800	62,900	32.5	58	121
	Transverse	45,300	43,500	63,300	33.5	56	
Normalized—15 min in salt bath at 1700° F, air cooled	Longitudinal	42,700	40,000	62,500	32.5	61	121
	Transverse	42,500	40,400	63,100	30.5	58	
Normalized as above, plus 2 hr anneal at 1200° F	Longitudinal	37,300	35,300	58,500	35.5	64	113
	Transverse	36,700	35,900	58,500	35.0	61	

* Acid-soluble aluminum.

† Indenter perpendicular to plate surface.



(a) (b)

Fig. 1 (a) Photomicrograph of typical inclusions, longitudinal section near center of gage (magnified 100 X). Comparison with (b) shows the greater average length of inclusions in the longitudinal direction. (b) Photomicrograph of typical inclusions, transverse section near center of gage (magnified 100 X). The inclusions in both of these views were mostly manganese sulfide with some silicates present

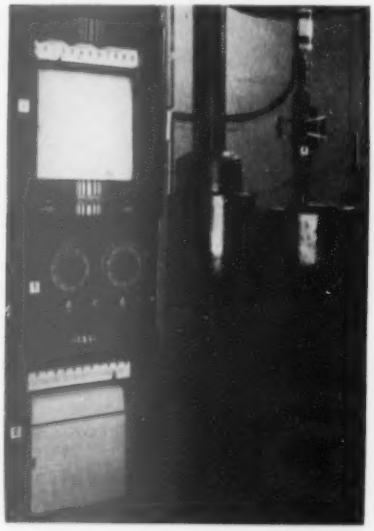


Fig. 3 Setup for modified Navy tear test: (1) X-time recorder, (2) X-Y recorder, (3) helipots for balancing strain gage bridge circuits, (4) specimen in position for test

ratory normalizing and annealing treatments. The chemical, tensile and hardness values obtained on this plate are given in Table 1. The steel was considered to be relatively clean. In Fig. 1 it may be noted that the longitudinal and transverse views show the usual elongation of inclusions in the direction of rolling. The material in the as-received condition had a fine grain size, No. 8 ASTM, and a moderately banded microstructure which is illustrated in Fig. 2(*A*). The yield point and microstructure indicated that the plate had been finished "cold" in hot rolling with the probability of some residual stresses. Normalizing increased the grain size to No. 7 and reduced the amount of banding, Fig. 2(*B*).

Equipment

An essential part of obtaining dW/dA values is the measurement of the area under the X-Y curve relating instantaneous values of the load X to the strain Y in the tear test. Both load and strain were measured by SR-4 electric resistance strain gage circuits and were registered on X-Y and X-time recorders having a 1-sec response time on the horizontal scale. The two X circuits could be exactly matched in output so that the X-time record indicated time at any point on the corresponding X-Y curve and over-all test times could be measured accurately. Some views of the apparatus and related accessories are shown in Figs. 3 to 7, inclusive. The clip gages were a critical item; the final models were made of 24S-T4 aluminum alloy after a design suggested in the literature.[3] The micrometer instrument used to calibrate the clip gages is illustrated in Fig. 8. The strain signals were additive to take care of slight misalignment. The temperature-compensated d. c. Wheatstone bridge circuits for load and strain measurement are given in Figs. 9 and 10. A 120,000-lb capacity testing ma-

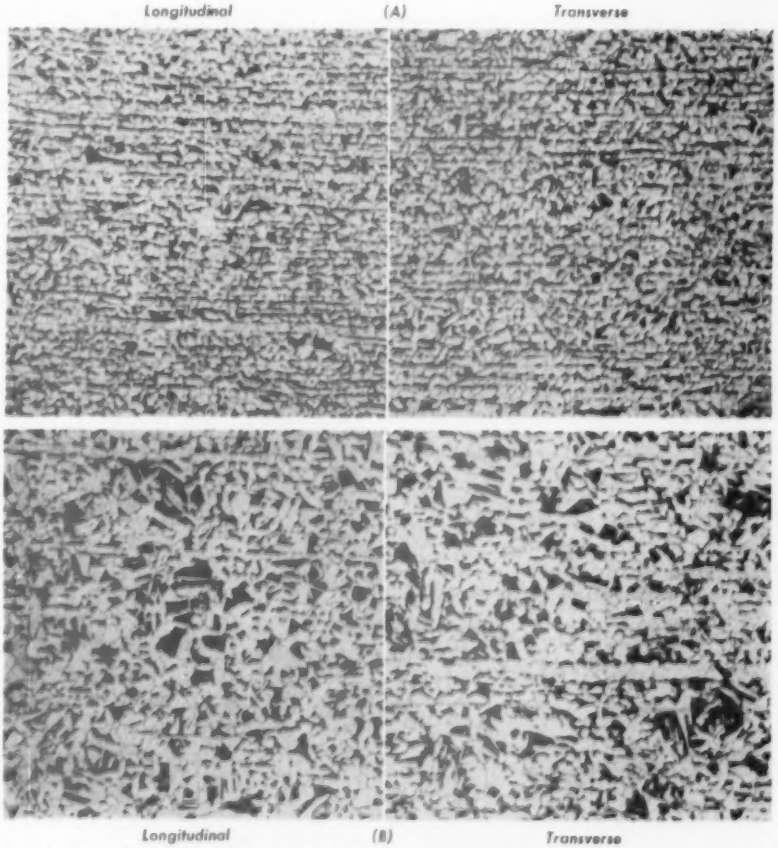


Fig. 2 Typical microstructures of mild steel plate (magnified 100 X, nital-picral etch). (A) Series F, mild steel plate as-received. ASTM grain size No. 8. (B) Series G, mild steel plate after normalizing at 1700° F for 15 min, followed by air cooling. ASTM grain size No. 7. The series H plate with an additional anneal of 2 hr at 1200° F had approximately the same microstructure

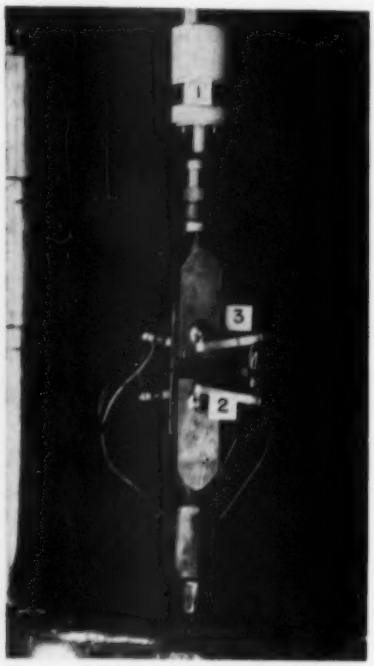


Fig. 4 Side view of tear test: (1) load cell, (2) clip gages, (3) specimen

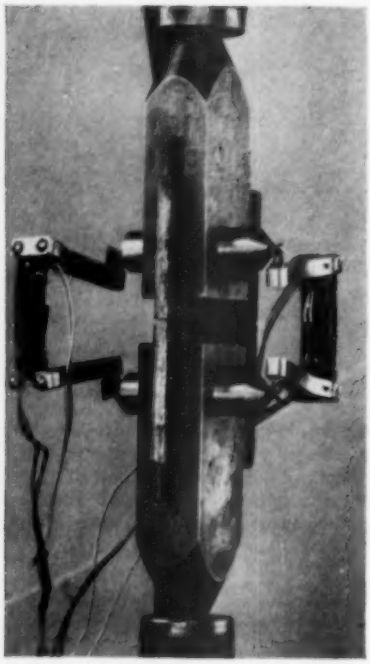


Fig. 5 Three-quarter view showing clip gages in position (the tear test specimen is a dummy which does show prior initiation of the fracture)

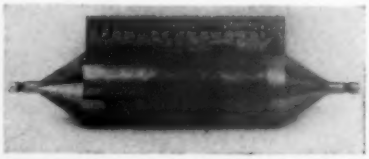


Fig. 6 Pin for applying load to the tear test specimen—hardened steel cylinder, $^3/_4$ in. diam, with reduced and grooved ends (soft steel inserts) to hold clip gages

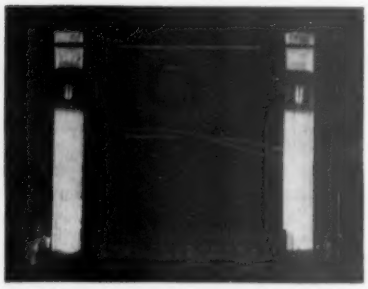


Fig. 7 Clip gage for measuring strain. The flexible spring blade and arms were made of 24S-T4 aluminum. Two A-5 SR-4 strain gages were cemented on opposite sides of the spring blade. The notched knife edges were made of beryllium copper

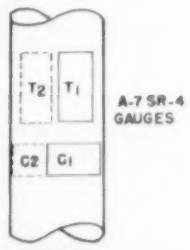
chine was used to apply load and the SR-4 load circuit was calibrated directly from the testing machine dial.

The standard Navy tear test is based on the design of N. A. Kahn and E. A. Imbembo.[2] H. M. Schnadt introduced the use of a hard steel roller bearing in the compression zone of Charpy-like impact specimens to minimize plastic deformation.[4] In applying Schnadt's principle to the Navy tear test, the modified design in Fig. 11 was determined by experiment.

Procedure

The specimens in a given series were cut from one area and numbered in sequence. For close study of a variable, alternate or adjacent samples were used when available. An advantage of the tear test is the ease of specimen preparation since a precise group of samples can be prepared by careful sawing and drilling. It should be noted in defining dW/dA that transverse tests are pulled apart across the rolling direction, i.e., the fracture runs *parallel* to the rolling direction.

An initiated crack is used in dW/dA measurement because the starting of a crack usually has a different energy requirement than the running of a crack. The crack is initiated by pulling the specimen slowly apart while the notch is under observation with a microscope having a large free working distance as shown in Fig. 12. The crack starts at the center of the plate thickness and is continued until it extends the full thickness of the plate. At this point the load is held constant and a drop of India ink containing aerosol wetting agent is placed on the crack and washed in with acetone.[5] The load is removed and the specimen is taken out and allowed to dry. The ink spot marks the area of the initiating crack when the specimen is later torn in two.



WEIGH BAR
HALF OF BRIDGE ON OPPOSITE SIDE OF BAR SHOWN DOTTED

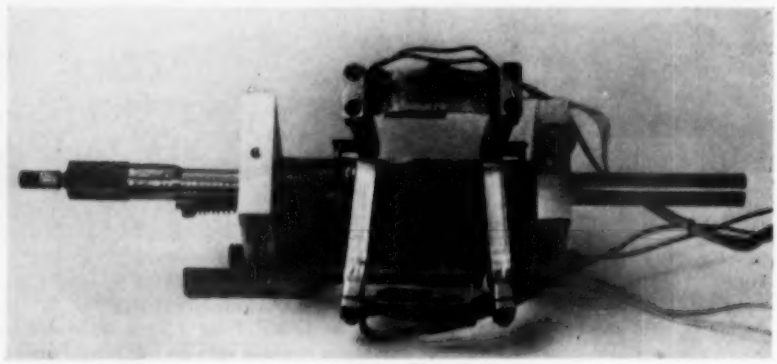
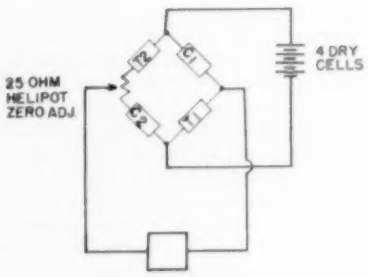


Fig. 8 Micrometer for calibrating clip gage movement



X OF X-Y OR
X-TIME RECORDER

Fig. 9 Diagram of circuit for measuring load

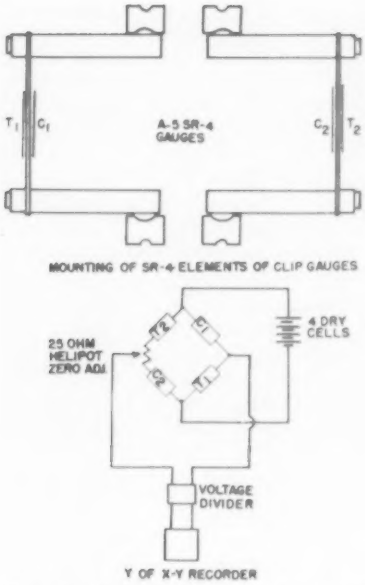


Fig. 10 Diagram of circuit for measuring strain

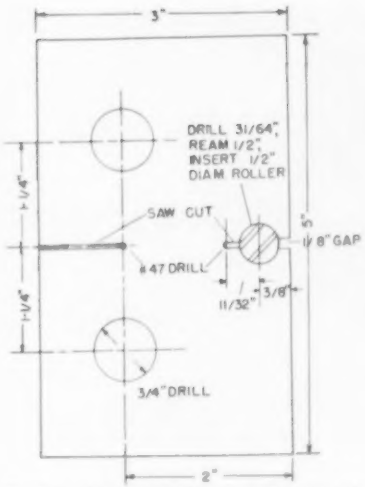


Fig. 11 Modified Navy tear test specimen for measuring work of ductile fracture propagation

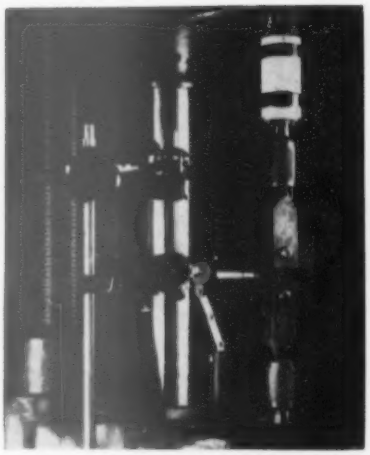
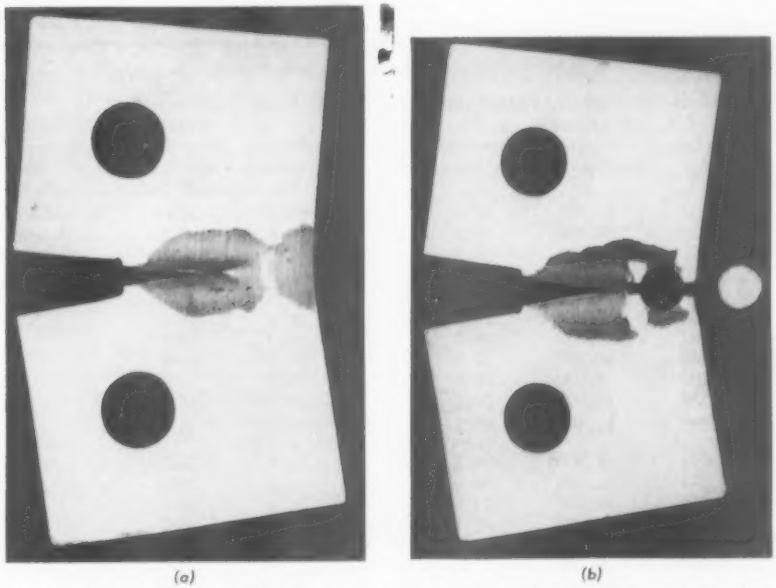


Fig. 12 Setup for observing fracture initiation (the binocular microscope was moved back slightly to show spotlight illuminating the notch)

With a properly selected size of drilled-hole notch, the maximum load in fracture initiation was greater than the maximum load during the tear test. This produced prestraining so that local yielding which developed around the $^3/_4$-in. holes during initiation did not recur during the tear test. By the use of brittle lime coatings applied after initiation, the areas of plastic flow in the subsequent tear test were shown to be closely confined to the fracture zone with very little extraneous deformation.

The calibration of load and strain circuits was found to remain constant during a series of tests. In calibrating the load circuit, a dummy unnotched specimen of high-strength steel was used. The recorder range was adjusted to give a load unit of convenient size so that the X-Y curve extended about half-way across the chart. Clip gage movement during strain calibration was kept similar to the range of movement in the tear test. The clip gage bridge output entered a voltage divider adjusted to give a suitable value of strain on the Y or vertical movement of the X-Y recorder. Time was obtained from an electric clock drive in the X-time recorder which was set to advance the chart 1 in. in 30 sec, in these tests.

The area under the X-Y curve was measured by planimetry to determine the work of fracture, dW. The dA value used in dW/dA was calculated as the original cross-sectional area of the fracture zone before testing minus



(a) (b)

Fig. 13 (a) Series A standard tear test specimen at finish of test using double inking method. The extent of plastic deformation was shown by the flaking of the brittle lime coating. Proceeding to the right from the end of the tear the following are visible (a) a remaining tension zone, (b) a neutral axis (white) and (c) a compression zone. (b) Series B modified tear test using the Schnadt roller principle. The areas from which the coating flaked showed that most of the plastic deformation was confined to the tension zone around the tear fracture with only a small compression zone in the part touching the roller

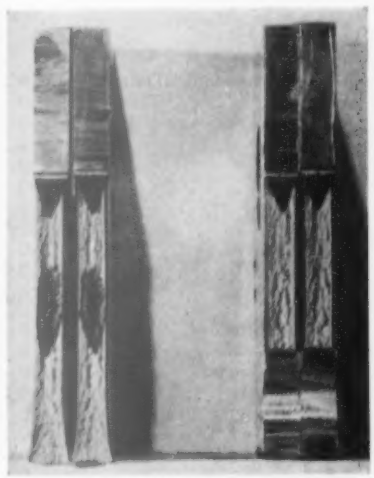


Fig. 14 Typical tear test fracture surfaces of Series A and Series B specimens. Series A *(left)* shows two ink spots marking initiation and termination of the measured fracture. Series B *(right)* shows one ink spot marking initiation of the full width fracture

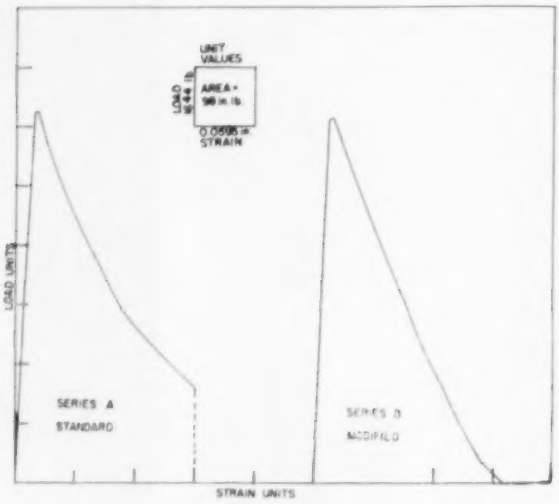


Fig. 15 Typical load-strain (*X-Y*) curves from tear tests in Series A and B

the original area of the triangular ink spot formed during initiation. Fracture width was measured with an optical scale to determine reduction in thickness. The standard error of the mean dW/dA was computed for each series. The differences between series were rated as significant (95% confidence) or highly significant (99% confidence) by the "*t*" test. All tests were run at room temperature, approximately 80° F and with a total tear time of about 25 sec or more, representing a slow strain rate.

PART I—DEVELOPMENT OF MODIFIED TEST

Design Modification

The value of Schnadt's method for eliminating unwanted plastic work was demonstrated by Series A and B tear tests. In the standard design of Series A, a second ink mark was used to determine the increase in area of the measured fracture. The work recorded was primarily from fracture in the tension zone formed by bending of the specimen but additional work was being expended in the compression zone. In Series B the compression work was minimized and the fracture was terminated by a notch in the tension zone. The data are given in Table 2 and typical results are illustrated in Figs. 13, 14 and 15. The following dW/dA values were obtained.

Series A, standard, transverse—4525 ± 272 in.-lb/in.².

Series B, modified, transverse—3200 ± 142 in.-lb/in.².

The lower dW/dA of the B series reflected the reduction of plastic deformation in the compression zone by using the hardened steel roller. The flaking of the brittle lime coatings in Fig. 13 and the widths of fracture in Fig. 14 showed that most of the plastic flow was restricted to the region of the tensile tear fracture in the case of the Series B specimens.

As shown in Fig. 14, the constant width of fracture in Series B demonstrated that a uniform lateral contraction had occurred throughout the length of the fracture. This indicated that the instantaneous values of dW/dA were nearly constant over the approximately 1-in. length of tear fracture. The uniform downward slope in the postmaximum part of the Series B *X-Y* curve in Fig. 15 also confirmed the concept of a nearly constant dW/dA over the tear length. The original Schnadt design for Charpy-like impact specimens required a large relative size of roller.[4] The reduced roller size

Table 2—Comparison of Standard and Modified Types of Tear Test Specimen

(Complete data from Series A and B tests on mild steel plate, 1/4 in. thick, as-received)

Specimen No.	*Type of specimen*	*Test direction**	*Original thickness, in.*	*Fracture area, in.²*	*Maximum load in propagation, lb*	*Total time of test,† sec*	*Hardness, R_B*	*Reduction in thickness, %*	*Work of fracture, dW/dA, in.-lb/in.²*	*Standard deviation of dW/dA, in.-lb/in.²*
A-1	Standard	Transverse all tests	0.246	0.230	10,500	32.5	67.0	30.9	5090	272, based on all tests
A-2			0.247	0.226	9,950	29.2	66.4	29.6	4480	
A-3			0.247	0.232	10,700	28.3	65.8	31.2	4610	
A-4			0.246	0.230	10,100	26.6	66.2	30.9	4490	
A-5			0.246	0.220	10,300	25.8	66.7	30.9	4520	
A-6			0.247	0.236	10,850	26.6	66.4	29.6	4620	
A-7			0.250	0.237	10,850	26.2	66.2	30.0	4600	
A-8			0.250	0.240	10,700	27.3	66.1	28.0	4540	
A-9			0.250	0.232	9,900	25.8	66.4	28.0	3960	
A-10			0.248	0.238	10,500	25.2	66.8	28.8	4345	
Avg			0.248	0.232	10,400	27.4	66.4	29.4	4525	
B-1	Modified, with roller	Transverse, all tests	0.250	0.274	9,900	29.2	65.1	30.8	3335	142, based on all tests
B-2			0.249	0.274	10,350	28.7	66.9	31.7	3465	
B-3			0.248	0.275	10,100	28.7	66.9	30.2	3105	
B-4			0.249	0.269	9,950	27.1	67.6	31.7	3085	
B-5			0.248	0.272	10,200	27.9	67.3	29.4	3245	
B-6			0.248	0.269	10,100	27.1	67.8	29.4	3235	
B-7			0.248	0.272	10,350	26.6	64.4	31.4	3125	
B-8			0.241	0.265	10,000	25.0	65.2	31.5	3170	
B-9			0.241	0.270	9,850	25.4	66.0	31.5	3385	
B-10			0.241	0.266	9,700	25.0	65.0	31.5	3050	
B-11			0.241	0.267	9,700	24.5	66.8	31.5	2965	
Avg			0.246	0.270	10,000	26.8	66.3	31.0	3209	

* Load applied as indicated with reference to the rolling direction.

† This includes time to reach maximum load and time of tear fracture.

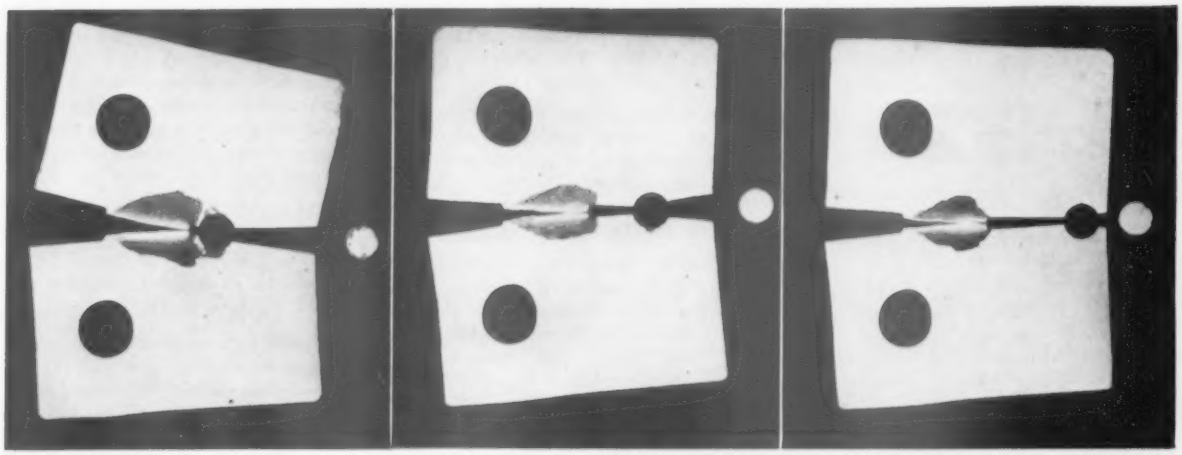


Fig. 16 Special 4-in. wide tear tests illustrating the effect of shifting the roller fulcrum. A brittle lime coating was applied after the crack was initiated. (*a*) $^1/_2$-in. diam roller in the standard position. Series C. (*b*) Roller moved $^1/_2$ in. outward from the standard position. Series D. (c) Roller moved 1 in. outward from the standard position. Series E

was found advantageous in the tear test to provide outer arms of metal for holding the roller in place and an inner notch to give sharp termination of the tear fracture.

The mean value of 3200 in.-lb/in.^{2} for dW/dA in Series B was in reasonable agreement with the values grouped around 3000 in.-lb/in.^{2} reported from slow bend tests on notched bars of mild steel ship plate.[6] The similarity of values indicated that the modified tear test was giving a dW/dA of the correct order of magnitude.

The Effect of Varied Stress Conditions on *dW/dA*

The wide specimens in the Series C, D and E transverse tear tests, shown in Fig. 16 with brittle lime coatings, were designed to vary stress distribution over a fixed location of tear fracture.

Using specimens 4 in. instead of 3 in. wide a 1-in. shift of the roller bearing was obtained without changing the location of the fracture zone. Angular displacement was measured on originally parallel ink lines drawn on the specimen, Fig. 17. The movement of these lines was photographed during the tear test with a 35-mm camera operating at a rate of 8 frames per second.

By shifting the roller outward $^1/_2$ in. (Series D) and 1 in. (Series E), a higher stress was produced over the crack length and there was a reduced angular movement of the test halves during fracture. The changed relations of stress and strain are illustrated by the X-Y curves in Fig. 18. Notwithstanding these variations, the dW/dA values and reduction in thickness remained

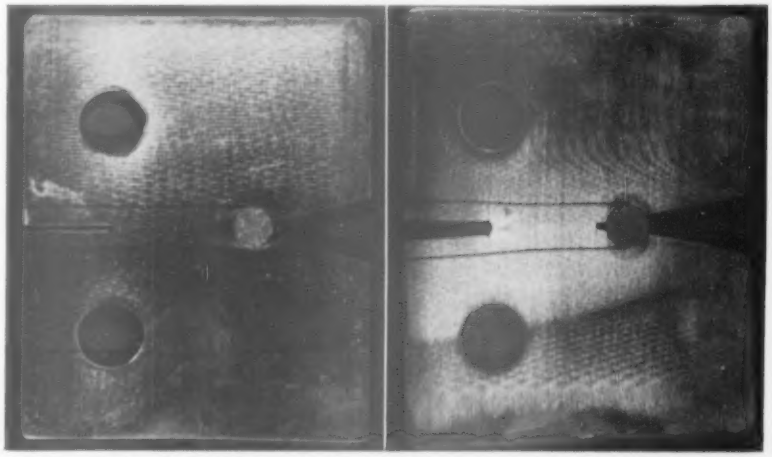


Fig. 17 Photographs of special wide tear test specimen showing location of the angle measurements. (*A*) Specimen before test showing ruled ink lines $^1/_2$ in. apart on surface prepared by grinding. (*B*) Specimen after the initiation of the tear fracture. The angle measurements were made on the lines parallel to the 1-in. deep saw-cut shown on the left side

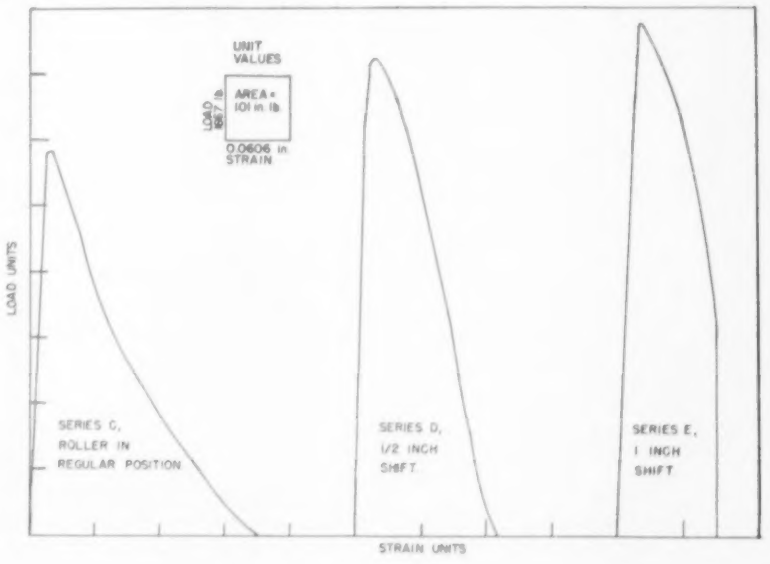


Fig. 18 Typical load-strain curves from tear tests in Series C, D and E

Table 3—Special 4-In. Wide Tear Tests Illustrating the Effect of Shifting the Roller Fulcrum

(Averages of data from Series C, D and E tests on mild steel plate, 1/4 in. thick, as-received)

Series	Type of specimen	No. of tests	Test direction*	Original thickness, in.	Fracture area, in.²	Maximum load to initiate crack, lb	Maximum load to propagate crack, lb	Total time of test,† sec	Hardness, R_B	Reduction in thickness, %	Initial angle at zero load after initiating crack	Initial angle under maximum load	Final angle at end of fracture	Work of fracture, dW/dA, in.-lb/in.²	Standard deviation of dW/dA, in.-lb/in.²
C	Modified, roller in normal position, all tests	12	Transverse	0.232	0.253	10,830	9,510	25.9	66.0	32.3	6° 15′	7° 30′	16° 20′	3440	140
D	Modified, roller moved 1/2 in. outward, all tests	12	Transverse	0.235	0.272	12,900	12,000	14.9	66.5	32.7	6° 36′	7° 35′	11° 16′	3370	121
E	Modified, roller moved 1 in. outward, all tests	12	Transverse	0.237	0.247	14,020	12,785	23.9	66.2	33.8	7° 3′	8° 0′	10° 30′	3340	207

* Load applied as indicated with reference to the rolling direction.

† This includes time to reach maximum load and time of tear fracture.

relatively unaffected by the roller shift as indicated by Table 3 and the bar charts in Fig. 19. The following dW/dA values were obtained:

Series C, transverse, roller in standard position—3440 ± 149 in.-lb/in.².
Series D, transverse, roller moved 1/2 in. outward—3370 ± 121 in.-lb/in.².
Series E, transverse, roller moved 1 in. outward—3340 ± 207 in.-lb/in.².

These values were not significantly different. The insensitivity to varied stress and strain conditions as noted above leads one to believe that dW/dA is a characteristic and reproducible value for ductile steel.

PART II—APPLICATION OF TEST TO MILD STEEL PLATE

The Effect of Rolling Direction

Plates usually fracture more easily along a direction parallel to the principal rolling direction, the so-called "weak way" of the plate which is measured by transverse tests. Longitudinal and transverse tear tests on the as-received plate are given as Series F in Table 4 and typical X-Y curves are shown in Fig. 20. The dW/dA values were:

Series F, as-received, longitudinal—4575 ± 376 in.-lb/in.².
Series F, as-received, transverse—3675 ± 89 in.-lb./in.².

The difference is significant.

Since the microstructure in the as-received plate showed pronounced banding, Fig. 2(A), normalizing and annealing treatments were applied to the plate material in order to redistribute the pearlite more uniformly, Fig. 2(B), and to remove residual rolling stresses

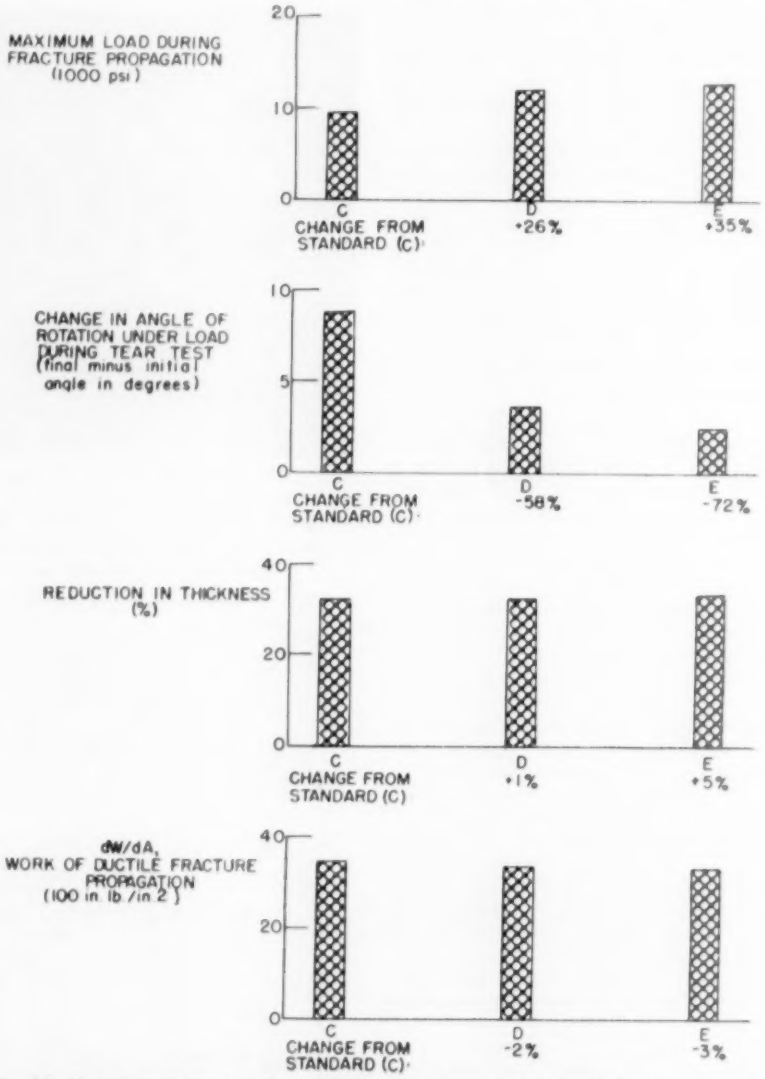


Fig. 19 Bar charts based on Series C, D and E showing that large changes in tear test conditions from roller shift produced only minor changes in the reduction in thickness and the work of ductile fracture propagation

Table 4—Tear Tests Illustrating the Effect of Rolling Direction and of Heat Treatment, Mild Steel Plate, ¼ In. Thick

(Complete data from Series F and averages of data from Series G and H)

Specimen No. or series	Heat treatment	Type of specimen	No. of tests	Test direction*	Original thickness, in.	Fracture area, in.²	Maximum load to initiate crack, lb	Maximum load to propagate crack, lb	Total time of test,† sec	Tear time only, sec	Hardness, R_B	Reduction in thickness, %	Work of fracture, dW/dA, in-lb/in.²	Standard deviation of dW/dA, in-lb/in.²
F-L1	As-received	Modified	...	Longitudinal, all tests	0.249	0.279	12,400	11,420	38	27	69	35.7	4090	376, based on all tests
F-L2					0.250	0.275	12,240	11,320	38	27	69	38.0	4525	
F-L3					0.248	0.273	12,400	11,520	38	26	68	37.5	4645	
F-L4					0.249	0.279	12,200	11,350	39	28	68	35.7	4410	
F-L5					0.247	0.272	12,200	10,800	38	27	67	37.2	4105	
F-L6					0.248	0.279	12,260	11,260	40	29	68	35.5	4700	
F-L7					0.244	0.264	11,920	10,840	...	...	68	36.5	5035	
F-L8					0.246	0.266	11,940	10,540	40	29	67	37.0	5095	
Avg					0.248	0.273	12,195	11,130	38	27	68	36.6	4575	
F-T1	As-received	Modified	...	Transverse, all tests	0.251	0.278	11,700	10,860	33	23	69	33.0	3750	89, based on 7 tests
F-T2					0.251	0.275	11,660	10,800	35	24	67	32.3	3685	
F-T3					0.252	0.277	11,720	10,670	37	24	67	30.6	3585	
F-T4					0.252	0.277	11,860	10,780	33	22	68	30.6	No data	
F-T5					0.253	0.278	12,100	11,270	32	21	67	30.6	3605	
F-T6					0.251	0.271	11,940	10,920	31	20	67	32.8	3610	
F-T7					0.243	0.264	11,200	10,150	31	25	66	33.0	3660	
F-T8					0.243	0.263	11,220	10,330	34	22	68	33.4	3815	
Avg					0.250	0.273	11,675	10,725	33	23	67.5	32.0	3675	
G-L	Normalized	Modified	8	Longitudinal	0.261	0.285	12,570	11,340	44	33	63.6	36.7	5660	188
G-T	Normalized	Modified	8	Transverse	0.261	0.281	11,880	10,660	39	28.6	63.2	34.5	4590	169
H-L	Normalized & annealed	Modified	8	Longitudinal	0.255	0.281	11,885	11,090	56	42	61.0	41.4	5660	280
H-T	Normalized & annealed	Modified	8	Transverse	0.254	0.273	11,260	10,410	45	33	62.0	38.4	5025	194

* Load applied as indicated with reference to the rolling direction.

† This includes time to reach maximum load and time of tear fracture.

if present. The physical properties obtained by heat treatment were given in the description of material.

Series G and H in Table 4 and Fig. 20 represented tear tests on the heat-treated plates. The following dW/dA values were obtained:

Series G, normalized, longitudinal—5660 ± 188 in.-lb/in.².

Series G, normalized, transverse—4590 ± 169 in.-lb/in.².

Series H, normalized and annealed, longitudinal—5660 ± 280 in.-lb/in.².

Series H, normalized and annealed, transverse—5025 ± 194 in.-lb/in.².

Comparing longitudinal and transverse results, it was observed that Series G showed a highly significant difference and Series H approached a significant difference (90% confidence). The relative dW/dA values are shown graphically in Fig. 21.

In order to compare metal flow properties, true stress-strain curves were obtained on cylindrical specimens of the materials used in these series. The curves are shown in Fig. 22. Uniaxial or uniform stress prevailed up to the point N where necking began in the tensile test. Above N, gradually increasing necking introduced multiaxial stresses which have a more severe effect than uniaxial stress. T is the strain corresponding to tear test fracture and F is the approximate strain in tensile fracture. The comparison in Table 5 gives strain values at the points N, T and F and shows the nearly constant ratio observed between the distances NT and NF when projected on the strain axis. The amount of strain at the point N of incipient necking was nearly constant regardless of direction or heat treatment but differences were found in the tear test strain T and the tensile fracture strain F. The similar ratios of the projected strains $(NT)/(NF)$, suggested that the amount of multiaxiality in tear fracture bore a nearly constant relation to the multiaxiality required to cause tensile fracture.

Portions of the longitudinal and transverse stress-strain curves replotted together on a log-log scale in Fig. 23 showed practically no effect of rolling direction on strain hardening, measured by line slope, up to the point T; the main differences being that fracture occurred at a lower strain in transverse tests. The slight gap at the left end of the curves representing as-rolled plate indicated some initial directional effects, probably from residual rolling stresses, which disappeared with larger amounts of cold work.

The *directional* effects of rolling on dW/dA were not eliminated by almost complete removal of banding and re-

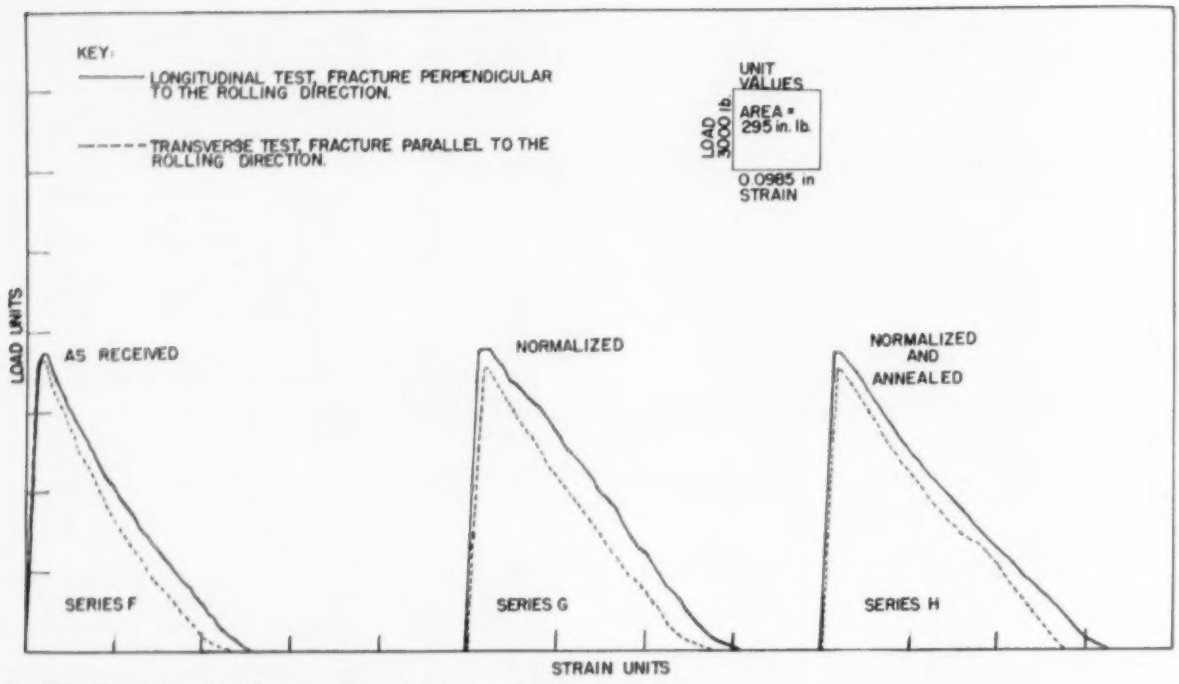


Fig. 20 Typical load-strain curves from tear tests in Series F, G and H

sidual stresses through heat treatment and there was no essential difference between longitudinal and transverse flow properties except for fracture at a lower strain in transverse tests. In agreement with recognized views on fracture it is believed that much of the difference between longitudinal and transverse dW/dA values is related to inclusions, particularly their elongated shape produced by rolling mainly in one direction.[7] The following is proposed as a tentative mechanism.

In transverse tests, torn the weak way of the plate, the pointed ends of the inclusions are sources of stress concentration and are aligned to assist the developing fracture. In longitudinal tests, the sharp inclusion ends run parallel to the principal stress field and thus do not act nearly in the same degree to promote fracture. This difference is shown schematically in Fig. 24.

A lower strain is required for tear test fracture than for tensile test fracture because the initiated tear fracture contributes an additional triaxiality ahead of its moving tip by inhibiting local plastic flow. In tensile test fracture there is no crack present until the specimen reaches an advanced stage of triaxiality associated with tensile fracture.

The Effect of Heat Treatment on dW/dA

The dW/dA values and some physical properties of the F, G and H series are regrouped in Table 6 for consideration of the changes resulting from heat treatment.

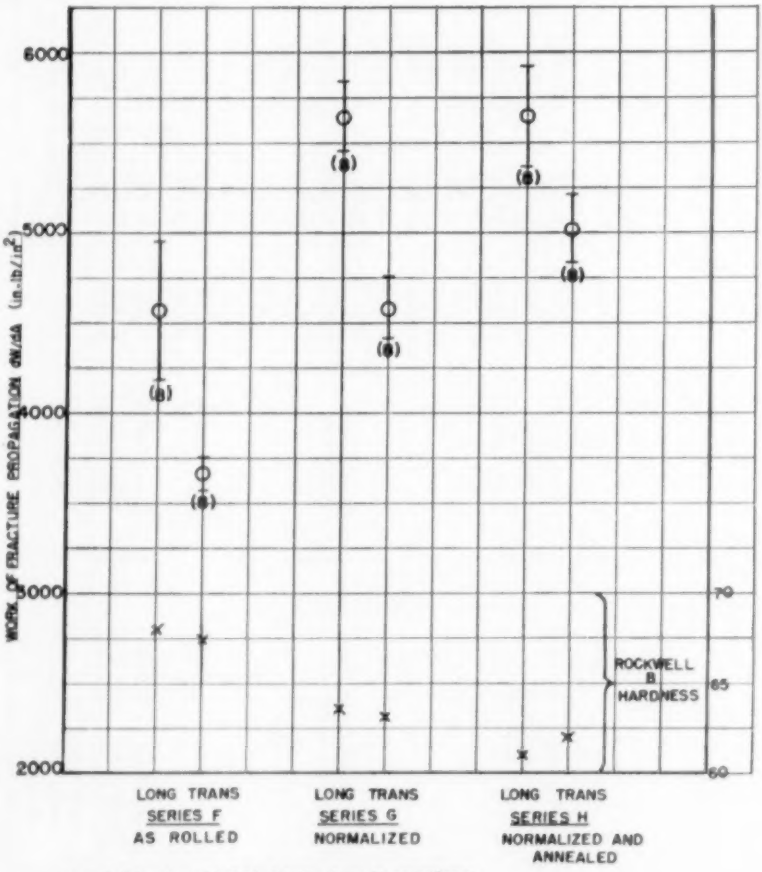


Fig. 21 Average dW/dA values with standard deviation of longitudinal and transverse tear tests of mild steel plate, $^1/_4$ in. thick, illustrating the effects of rolling direction and of heat treatment

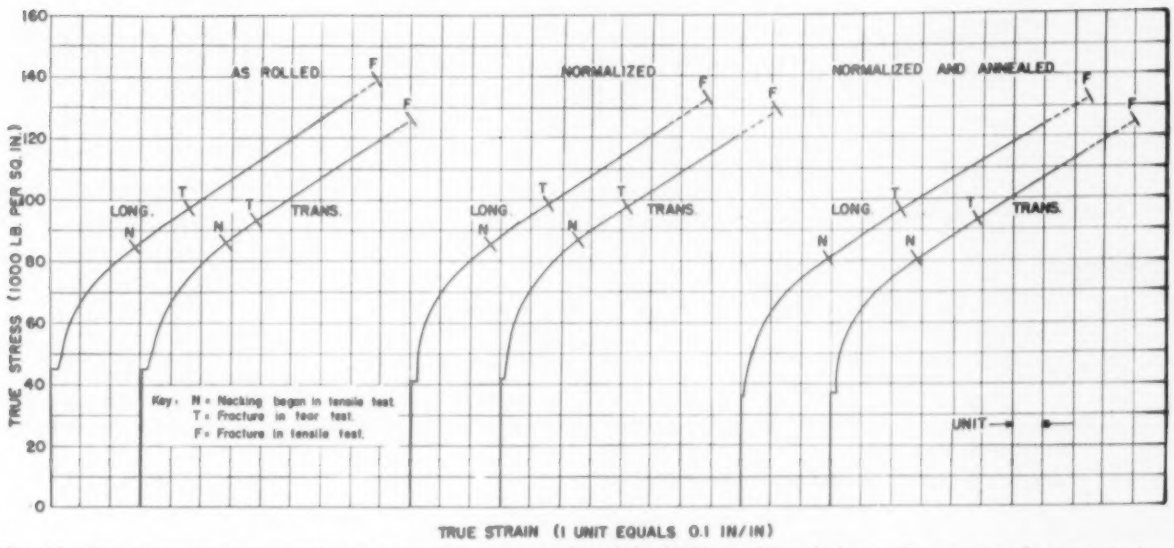


Fig. 22 True stress-strain curves showing metal flow properties of the 1020 steel in relation to the tear test fracture strain

The values were believed to represent correctly the influence of heat treatment since an inclusion study of the separate 20- by 20-in. sections used in the test indicated an average steel quality in each. In the longitudinal test, normalizing increased dW/dA significantly but an additional annealing treatment had no further effect even though the steel was softened considerably. In the more important transverse tests, normalizing produced a highly significant increase in dW/dA and annealing produced a further increase of probable significance (90% confidence). The general value of heat treatment would, of course, depend upon the original condition of the plate. There was a clear advantage in the plate under examination because of its probable "cold" finishing temperature in rolling.

Table 5—Strain Data

	As-rolled, in./in.		*Normalized*, in./in.		*Normalized and annealed*, in./in.	
	Long	*Trans*	*Long*	*Trans*	*Long*	*Trans*
N	0.28	0.28	0.27	0.27	0.27	0.29
T	0.46	0.38	0.46	0.43	0.53	0.48
F	1.09	0.91	0.99	0.92	1.15	0.99
NT projected, (T minus N)	0.18	0.10	0.19	0.16	0.24	0.20
NF projected, (F minus N)	0.81	0.63	0.72	0.65	0.86	0.71
Ratio $(NT)/(NF)$, %	22	16	27	25	28	28

Table 6—Effect of Heat Treatment

Series	*Longitudinal*, dW/dA, in.-lb/in.^{2}	*Transverse*, dW/dA, in.-lb/in.^{2}	*Transverse lower yield point*, psi	*Brinell hardness*, 1500 kg
F, as-received	4575 ± 376	3675 ± 89	43,500	121
G, normalized	5660 ± 188	4590 ± 169	40,400	121
H, normalized and annealed	5660 ± 280	5024 ± 194	35,900	113

Table 7—Metal Flow Properties and dW/dA in Transverse Tests

Series	*Flow strength at a strain of 0.2 in./in.*	*Strain hardening exponent, n*[*]	*Transverse*, dW/dA, in.-lb/in.^{2}
F, as-received	80,000	0.25	3675 ± 89
G, normalized	82,000	0.23	4590 ± 169
H, normalized and annealed	76,000	0.24	5025 ± 194

[*] From the slope of the log-log plot.

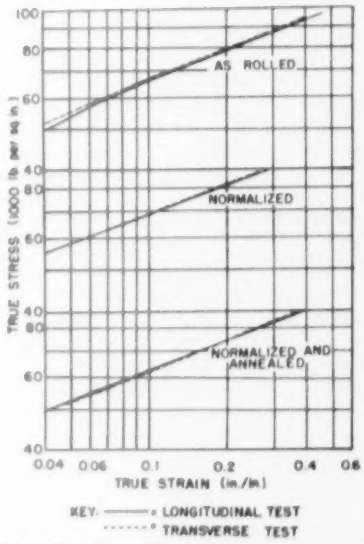


Fig. 23 The effect of heat treatment on 1020 steel as shown by true stress-strain curves plotted on log-log scale to strain at which tear fracture occurred

Parts of transverse true stress-strain curves on a log-log scale are compared graphically in Fig. 25. Values of the metal flow properties obtained from these curves and other pertinent data are listed in Table 7. There appeared to be no simple relation between transverse dW/dA and the flow properties. Since specific reasons cannot be assigned as yet for the observed variations in dW/dA with heat treatment, it will suffice to mention some factors of possible significance: inclusions, grain size, type of microstructure, residual stresses and flow properties. Whatever the cause of the increased transverse dW/dA from heat treatment,

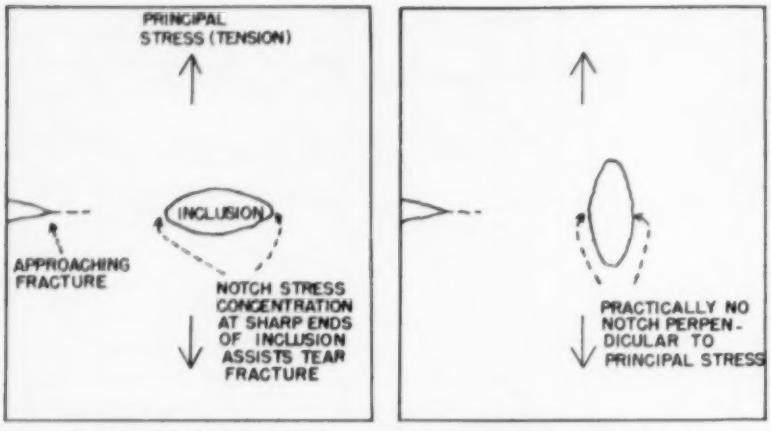


Fig. 24 Diagrams showing suggested effect of inclusion shape

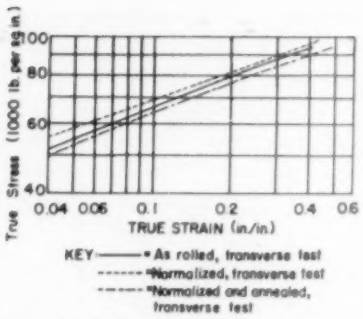


Fig. 25 Portions of true stress-strain curves of 1020 steel showing effect of heat treatment on transverse properties. Curves plotted on log-log scale to strain at which tear test fracture occurred

the gain itself is of potential interest since it indicates a relatively simple method of improving a low dW/dA value in some conditions of as-rolled plate.

If dW/dA were an important consideration for a proposed engineering use of this plate material, then normalized-only would probably be selected as the best of the three treatments since it combined high values of both yield point and resistance to tearing.

Characteristic dW/dA in Transverse Tests of Mild Steel Plate, As-Received

In considering the variation of dW/dA within a given plate, the mean and lowest values are probably of most importance. The nine series of transverse tests reported in Table 8 gave an averaged mean of 3700 in.-lb per square inch. The series values are plotted graphically in Fig. 26 in order of magnitude. If 3700 is taken as the statistical population mean of dW/dA for this particular plate, then six out of the nine series showed no significant difference from this mean. The other differences were: Series I, significant; Series B and N, highly significant.

From an over-all viewpoint, the plate had a consistent dW/dA over most of its area with, however, real variations in the extreme upper and lower values. Possible causes for the extreme variation were studied by comparing test samples which had given high (4550 in.-lb/in.^{2}) and low (3105 in.-lb./in.^{2}) values. Etched sections and corresponding microstructures are shown in Fig. 27. The inclusion ratings are given in Table 9. Half of the cross section (A-1 and A-3 in Fig. 27) of the sample with the highest dW/dA was a very clean steel with practically no banding. This condition may represent a high-purity zone near the ingot shell which would be apt to occur along the rolled edge of the plate. Unfortunately the original position of this sample could not be verified. However, there was a larger size and amount of inclusions in the sample with low dW/dA (Fig. 27, B-1) which would indicate a probable adverse effect of inclusion content on the level of transverse dW/dA.

Conclusions

A modification of the Navy tear test was found suitable for determining an approximate dW/dA in ductile metals. The test was used in an examination of one large plate of mild steel, 1/4 in. thick.

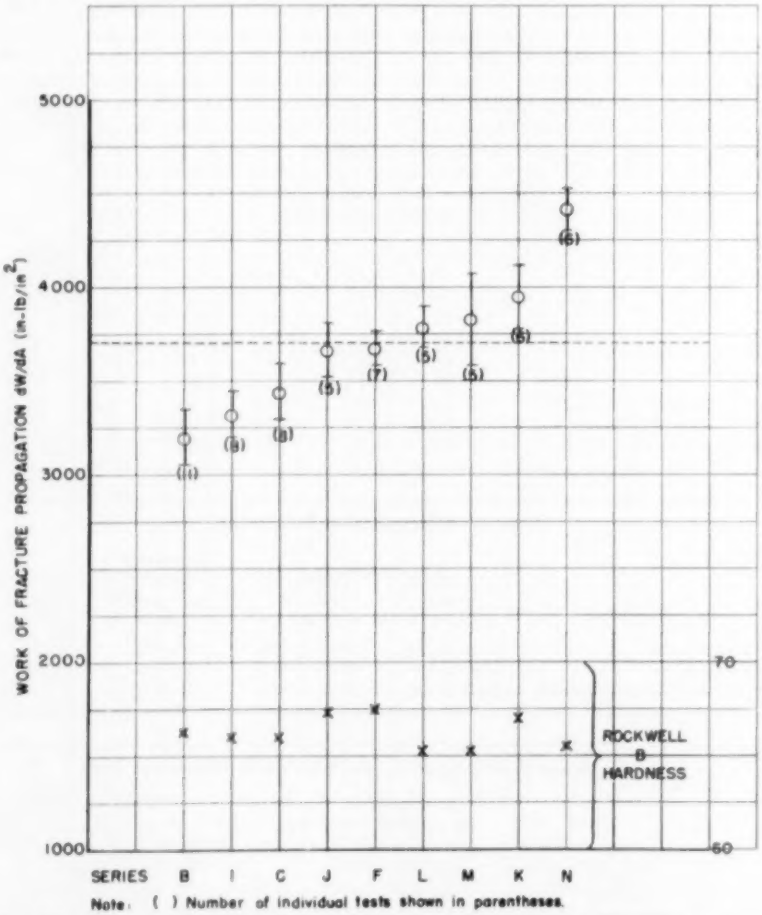


Fig. 26 Average dW/dA values with standard deviation of all transverse tear tests of mild steel plate, 1/4 in. thick, as-received. Data arranged in the order of increasing values

Table 8—Summary of Transverse Tear Tests on Mild Steel Plate—¼ In. Thick, in the As-Received Condition

(Modified tear test specimen with roller)

Series	No. of tests	Original thickness, in.	Fracture area, in.²	Maximum load to initiate crack, lb	Maximum load to propagate crack, lb	Total time of test, sec	Tear time only, sec	Hardness, R_B	Reduction in thickness, %	Work of fracture, dW/dA, in.-lb/in.²	Standard deviation of dW/dA, in.-lb/in.²
B	11	0.246	0.270	...	10,000	27	...	66.3	31.0	3200	142
C	12	0.232	0.272	10,830	9,510	26	...	66.0	32.3	3440	149
F	7	0.250	0.273	11,675	10,725	33	23	67.5	32.0	3675	89
I	8	0.246	0.268	11,420	10,110	34	24	66.0	31.2	3320	120
J	5	0.247	0.264	11,100	10,100	44	30	67.3	31.9	3670	139
K	6	0.237	0.261	11,190	9,870	36	26	67.0	30.6	3955	173
L	5	0.249	0.271	11,280	10,100	67	46	65.2	30.1	3790	114
M	5	0.220	0.241	10,350	9,350	67	47	65.3	29.8	3830	242
N	6	0.231	0.253	10,490	9,650	75	56	65.4	33.7	4420	114
									Grand avg	3700	

Significant differences in dW/dA were obtained between longitudinal and transverse tear tests, regardless of heat treatment. The lower dW/dA occurred in the transverse tests and was thought to be caused by the stress-raising effect of the sharp ends of inclusions elongated by rolling.

Transverse dW/dA was substantially improved by normalizing. A further increase obtained by an additional annealing treatment was accompanied by a considerable reduction in yield point. The most favorable combination of dW/dA and yield point was found in normalized-only plate.

Table 9—Inclusion Ratings of High and Low dW/dA Tests

	Location	ASTM Inclusion Rating
Sample with highest dW/dA	¼ section	A2, thin
	½ section	A3, thin
Sample with lowest dW/dA	Entire section	A3 to A4, heavy

The mean value of dW/dA in transverse tests of the plate in the as-received condition was 3700 in.-lb./in.², at room temperature and with a slow strain

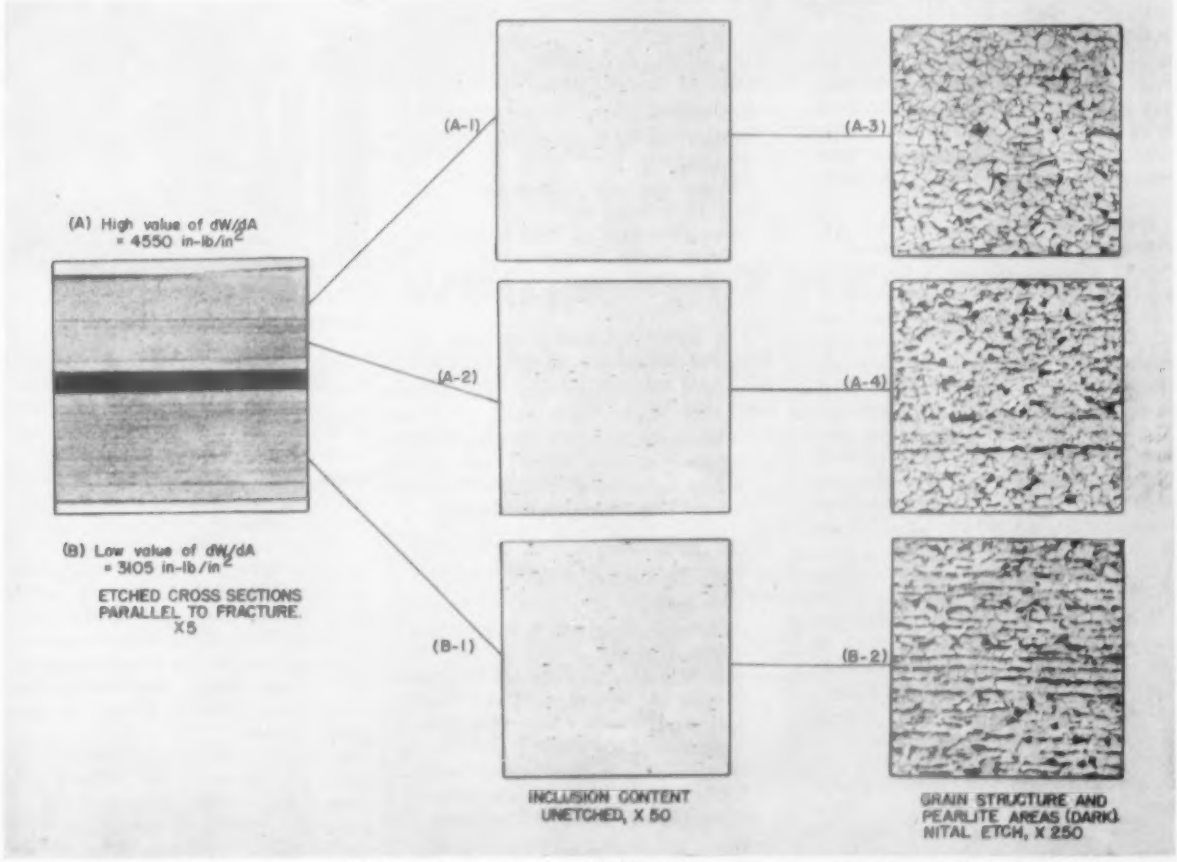

(A) High value of dW/dA = 4550 in-lb/in²
(B) Low value of dW/dA = 3105 in-lb/in²
ETCHED CROSS SECTIONS PARALLEL TO FRACTURE. X5
(A-1)
(A-2)
(B-1)
(A-3)
(A-4)
(B-2)
INCLUSION CONTENT UNETCHED, X 50
GRAIN STRUCTURE AND PEARLITE AREAS (DARK). NITAL ETCH, X 250

Fig. 27 Relation of microstructure to high and low values for dW/dA in transverse tests of mild steel plate, ¼ in. thick. (The magnifications shown are the original values.) (Reduced by 50% upon production)

rate. The lowest test value was about 3000 in-lb/in.²

A high inclusion content probably affected the level of transverse dW/dA unfavorably. Normalizing seemed to be effective in increasing dW/dA but this would depend upon the condition of the as-rolled plate. Other possible factors in dW/dA level, not clearly evaluated, may include grain size, microstructure, metal flow properties and residual stresses.

Acknowledgments

Aid received from the Naval Research Laboratory is gratefully acknowledged, particularly that from Joseph A. Kies and Martin W. Brossman in supplying apparatus which permitted preliminary evaluation of the test and in giving advice on fracture testing principles. The assistance in specimen design and in obtaining data by Ronald G. Hayes, Naval Proving Ground, is also acknowledged as contributing materially to the development of the test.

References

1. Irwin, G. R., "Fracture Dynamics," *Trans. ASM* 40A 147–166 (1948).
2. Kahn, N. A., and Imbembo, E. A., "A Method of Evaluating Transition from Shear to Cleavage Fracture in Ship Plate and Its Correlation with Large-Scale Plate Tests," THE WELDING JOURNAL, **27** (4), Research Suppl., 169-s to 186-s (1948); "Notch Sensitivity of Steel Evaluated by Tear Test," *Ibid.*, **28** (4), Research Suppl., 153-s to 165-s (1949).
3. Ball, L. M., *Strain Gage Technique*, Vol. III, No. 1, Society for Experimental Stress Analysis, p. 1 (1945).
4. Puzak, P. P., Eschbacher, E. W., and Pellini, W. S., "Initiation and Propagation of Brittle Fracture in Structural Steels," THE WELDING JOURNAL, **31** (12), Research Suppl., 561-s to 581-s (1952).
5. University of North Carolina Report No. 38, Naval Research Laboratory Contract N6ori-227 (1947).
6. Irwin, G. R., "Fracture Dynamics and Fracture Strength of Large Welded Structures," Ship Structures Committee Report No. SSC-69, p. 169 (May 1954).
7. Discussion with Dr. C. F. Tipper, Engineering Laboratory, Cambridge University, England, at the Naval Proving Ground, March 1954.

RESEARCH NEWS

Excellent Progress Being Made by WRC Interpretive Reports Committee

The Interpretive Reports Committee of the Welding Research Council, under the chairmanship of T. N. Armstrong, has been making excellent progress in the preparation of four interpretive reports. Subjects for reports are selected by the Interpretive Reports Committee after careful consideration of topics which industry believes should be covered by interpretive reviews. Subjects may be of a controversial nature, or on which a report is desired to aid code writing or research committees. Subjects are assigned by the Committee to outstanding experts.

These interpretive reports are not intended to be comprehensive literature reviews although, obviously, the author will draw freely on the literature. What is desired is a tightly written report on the present state of the knowledge that will bring the reader up to date. To do this, the author will have to select what he considers best in the literature and supplement it by drawing on his personal knowledge. A carefully selected bibliography, limited to not over approximately twelve of the best published references on the subject, will be included.

Each expert is expected to prepare a concise summary of the contents of the interpretive report. The committee may add to, or revise, the summary as the summary will appear under the committee's name when the report is published. The initial manuscript of each interpretive report is submitted to a small selected group of individuals who are well informed on the subject for review.

These reports are aimed at engineers and research workers who may not have had opportunity, because of limited time or circumstances, to become informed on the subject. The purpose is to furnish them with a brief of the knowledge in as useful a form as possible. In some instances, procedures or precautions for meeting difficulties can be presented. Also, where there are obvious gaps in the knowledge, a useful service will be performed in calling attention to them.

It is expected that the following reports will be completed during the calendar year 1955:

"Effect of Preheating on Weldments," by E. P. DeGarmo
"Stress Relieving of Weldments," by E. R. Parker
"Notch Ductility of Weld Metal," by W. S. Pellini
"Effects of Porosity," by W. E. McKenzie

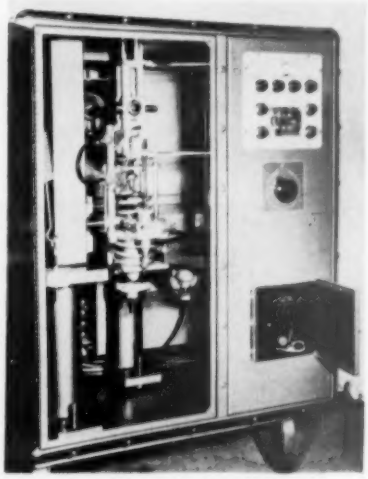
The committee held a meeting on June 2nd and tentatively selected three additional subjects for the fiscal year beginning Oct. 1, 1955:

"Welding of Type 347 Stainless Steel Pipe"
"Stress Relieving of Stainless Steels"
"Use of Low Hydrogen Electrodes"

The committee is also considering assignment on one of the following subjects:

"How Much Ductility Is Needed in a Welded Structure?"
"The Development of a Suitable Basis of Design or Yield Point Alone, Ultimate Alone, or a Combination of the Two"
"What Should Be the Basis of Design When Using Steels Whose Properties Depend on Heat Treatment?"

The committee would welcome further suggestions from industry as to suitable topics for interpretive reports.



Universal Fatigue Machine

Automatically maintained constant preload equipment is available on Sonntag simulated service fatigue machines of 400-lb load capacity, it has been announced by Baldwin-Lima-Hamilton Corp., Philadelphia 42, Pa. The necessary additional controls are shown on the panel in the accompanying photograph.

The new equipment for the SF-01-U universal fatigue machine is reported to correct automatically for creep which may be produced in test specimens such as machine parts or structural components while they are being subjected to constant fatigue loads in tension, compression, bending, torsion or combined stresses.

With maximum preload of 200 lb the maximum movement of the vertically reciprocating load platen is 0.625 ± 0.312 in. Maximum movement without preload is 1 ± 0.5 in. The machine has a $22^1/_2$ x $29^1/_2$-in. working table 42 in. high.

A revolving fixture holds this tubular steel chair-desk while the weldor brazes the joints with ANACONDA-997 (Low Fuming) Bronze Welding Rod. Heywood-Wakefield Company began producing welded steel tubing back in 1910. Today, they are leading manufacturers of tubular steel schoolroom furniture, bus, subway, railway car and theater seating.

here's production speed . . .

23 braze welds in 17 minutes

Here's the finished chair with seat, back rest and desk sections in place.

They know a lot about the techniques of production welding at Heywood-Wakefield Company, Gardner, Mass. Take the combination school chair-desk you see here. First it's tack-welded by semi-automatic resistance welding. Then it goes into a revolving fixture for braze welding with ANACONDA-997 (Low Fuming) Bronze Welding Rod and the flame-fluxed oxyacetylene process. The weldor swings the assembly to reach all joints from one position, completing the 23 welds in an average time of 17 minutes.

It's not only a fast job . . . it's a *good* job. The credit goes to Heywood-Wakefield engineers for their time-saving fixtures; to the weldor for his skill, and to the ANACONDA-997 rods he uses. Heywood-Wakefield prefers these rods because the finished welds are very strong, and they don't require special cleaning before painting. They're degreased, wire brushed . . . then painted. That's all.

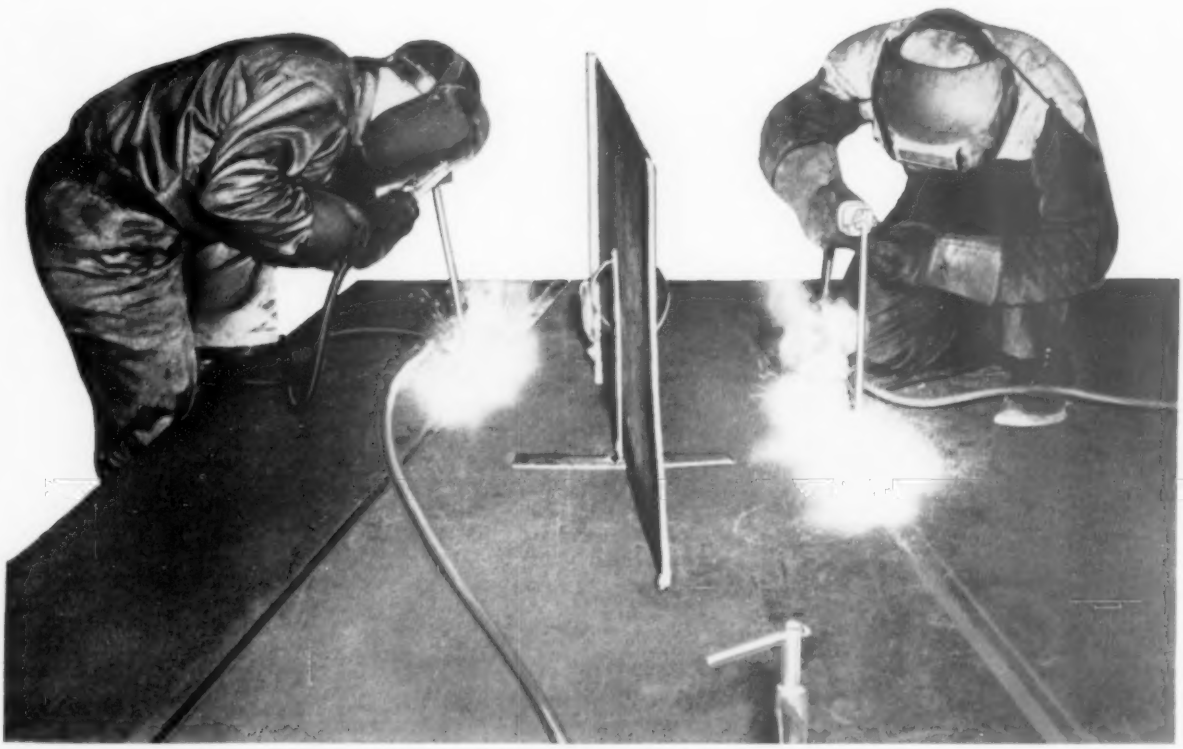
ANACONDA-997 (Low Fuming) Bronze is a superior welding rod used to join copper alloys, cast iron, malleable iron and steel by the oxyacetylene process. It is also used for repair welding, and to deposit bearing surfaces on steel and iron. You can get other ANACONDA Copper Alloy Welding Rods for many different repair and production welding purposes. They're sold by distributors of welding equipment everywhere. Anaconda distributors are also a good source of practical advice on welding problems. Pratt & Inman Company, Worcester, Mass., general distributors, furnish Heywood-Wakefield Company with ANACONDA-997 Welding Rods. For more information about ANACONDA Welding Rods and recommended welding procedures, write for a copy of Publication B-13. Address *The American Brass Company, Waterbury 20, Conn.* In Canada: *Anaconda American Brass Ltd., New Toronto, Ontario.* AA128

ANACONDA®

WELDING RODS

AT THE FRONTIERS OF PROGRESS YOU'LL FIND . . .

AN AIR REDUCTION PRODUCT



Fabricating ½-inch wrought iron pier plates with "Easyarc 12" electrodes. Powdered metal electrode coating actually becomes part of the weld deposit.

Easyarc 12 can cut welding costs in half

Airco's "Easyarc 12" contact electrode cuts welding time and costs two ways. (1) The electrode deposits more metal per kilowatt of arc energy than *any other welding process.* This is because the powdered metal coating actually becomes a part of the weld. (2) The "Easyarc 12" electrode can carry a higher current than conventional electrodes, without danger of breakdown. Users have reported cutting their production costs in half by using time-saving "Easyarc 12" electrodes. And you get all these other advantages:

Restrike – No need to trim electrode to restrike. A light touch will restore the arc.

Slag removal – Many users have found the fast cooling of Easyarc welds causes slag to curl up of its own accord. A slight rap knocks it off.

Appearance – "Easyarc 12" leaves a clean, smooth bead contributing to the over-all appearance of the finished product.

To help you select the *right* electrode for your welding job – whatever it may be – write for Airco Electrode Pocket Guide. It's free! Address your nearest Airco office. Ask for Catalog #1318. All Airco Electrodes are available through your Authorized Airco Dealer.

AIRCO®

AIR REDUCTION

60 East 42nd Street • New York 17, N. Y.

Divisions of Air Reduction Company, Incorporated, with offices and dealers in most principal cities

Air Reduction Sales Company
Air Reduction Pacific Company
Represented internationally by
Airco Company International
Foreign Subsidiaries:
Air Reduction Canada Limited
Cuban Air Products Corporation

Products of the divisions of Air Reduction Company, Incorporated, include: **AIRCO** – industrial gases, welding and cutting equipment, and acetylenic chemicals • **PURECO** – carbon dioxide, liquid-solid ("DRY-ICE") • **OHIO** – medical gases and hospital equipment • **NATIONAL CARBIDE** – pipeline acetylene and calcium carbide • **COLTON** – polyvinyl-acetates,—alcohols, and other synthetic resins.